VOLUNTEER HANDBOOK

CHAPTER 1 – SMALL GROUP SESSIONS

&

CHAPTER 1A – CARNIVALS

Updated 2021

Foreword

Welcome to Operation Einstein!

Operation Einstein is a community service project aiming to bring a unique form of scientific education to underprivileged children. Supported by the NUS Department of Physics, we bring a "minds-on" experience where students are exposed to toys, experiments and set-ups which demonstrate various scientific phenomena, and are encouraged to tinker around and ask questions to discover answers. As a volunteer, you will be engaging 7 to 15-year-old* students through conducting and explaining scientific demonstrations, with the aim of nurturing a passion for learning and an appreciation of the sciences.

**Our primary target audience is upper primary children aged 10-12, who have been exposed to science in school, Nonetheless, the "minds-on" approach applies regardless of age and background.*
***In the event where we have Mandarin-speaking audiences (usually during Carnival sessions), you may require this Chinese translation of this handbook & a Chinese glossary of physics terms.*

A note on our current programme structure:

Operation Einstein has developed three main programmes: Small Group Sessions, Carnivals, and Weekly Modules. This Handbook outlines Chapter 1 and Chapter 1A sessions, which comprise an identical set of demonstrations.

- **Chapter 1 - Small Group Sessions** *(group size: about 25 students)***:** Student beneficiaries will be brought through a series of 5 stations in a 2-hour session, where volunteers will use a demonstration to explain scientific concepts behind the phenomena. Each volunteer will be in charge of a group of 3-5 children.

- **Chapter 1A - Carnival Booth** *(group size: a flowing crowd of a few hundred)***:** Members of the public will visit our booth, where volunteers will use a demonstration to explain scientific concepts behind the phenomena. Each volunteer will be in charge of 1-2 experiments.

- **Chapter 2 - Weekly Modules** *(group size: about 25 students)***:** Every weekend, beneficiaries from a partner centre will participate in a 1.5-hour session, where they will learn about a set of scientific concepts through fun activities and experiments conducted by student volunteers. Towards the end of the programme, they will select a related topic of their choice to research more in-depth into, under the mentorship of a volunteer.

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Tips for Engaging Participants

Ice Breakers

Each group will be led by 1-2 group facilitators. After the introduction and storyline, the groups will be given some time to get to know one another:

1. Find a suitable location to sit the group down, preferably in a circle.
2. Introduce yourselves: name, age, school, hobby.
3. Ask if the kids know one another. If they do, get them to introduce one another. If not, do a quick round of self-introductions: name, age, school, hobby etc.
4. Ask them what they think of the ministeins. Check if they understood the storyline premise from the slides earlier. Explain/retell the sections of the story they failed to grasp. Once they are all clear, introduce the five ministeins: builder, miner, sleepy, drenched and musician; use the **flashcards**.
5. Play an ice breaker game, such as:
    a. Ministein says
    b. Never Have I Ever
    c. Thumb Game

Explaining the Science

As a volunteer, your job is not to spoon-feed answers, but rather, to guide the beneficiaries in finding the answers to their questions for themselves. While this handbook serves as a guide, feel free to try out new methods of explaining the concepts; if it works, be sure to let us know so we can include it in the future!

When explaining scientific concepts to participants, you may find it useful to follow a step-by-step approach (which is reflected the handbook):

1. **Activity/Demo:** Physical and/or visual representation of a scientific concept to capture participants' attention and encourage them to ask questions.
   **Activities involve participants physically engaging with the experiment; Demos are conducted by volunteers and only require participants to observe - due to risks or physical limitations.*
2. **Ask, Engage, Explain:** Ideally, the participants can start asking questions which you may answer. However, in most cases, you may find it useful to structure your explanation as questions you can ask: This helps to engage participants and also gauge their understanding based on their answers. In the worst-case scenario, you may simply end up answering your own questions. Some tips you may apply here include:
    a. Repeat after you (a certain new word or phrase, such as "centripetal force")
    b. Use analogies and real-life examples
3. **Test Understanding:** Once done explaining, ask questions to test their understanding. Hopefully, their answers will prove that they grasp the concepts; Otherwise, just correct their errors and encourage them to keep up the spirit of learning!

Station 1 – Builder Stein

1.1 Balancing Bird

STORY:

EQUIPMENT/PROPS:

1. Balancing Bird *(refer to picture)*
2. Long ruler
3. Broom/Mop

SCIENTIFIC CONCEPT(S):

1. Centre of Gravity

RECOMMENDED FLOW OF EXPLANATION:

- **"How can I balance this bird on my fingertip?"** Get responses and perform the demonstration.

- **"Why is the bird balancing its beak on my fingertip? Why not the tail, body or wings?"** Direct their answers towards "centre (of gravity)", then explain centre of gravity: All the weight of the toy acts on one point (i.e. point where object balances). If required, explain gravity: All mass is pulled down towards Earth

- **(ACTIVITY) "Where is the centre of gravity?"**
  - Ask the students to find the centre of gravity of a ruler, then a broom.
  - Demonstrate that by starting with both hands at each end of the broom and moving the hands towards the centre, one will end up with the broom balanced at its centre of gravity. Show that it works the same for the ruler.

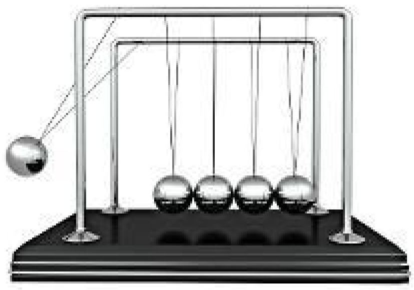
- **"What happens if you try to tip the bird over? Or if you flip the bird upside down?"** Let the students try it out.

- **"Why does the bird return back to its original position? How is the weight of the bird spread out?"** Show that the weight of the bird is at the wings and tail respectively. Explain that the centre of gravity acts from a point perpendicular to the ground, and whether it tips over or returns back to its original position depends on whether this vector is above the contact point between the object and the ground.

- **(ACTIVITY) "Where is YOUR centre of gravity?"**
  - Get the students to stand on one leg, and perform various actions (eg. stretch out both arms to one side). At each position, ask them where their centre of gravity is – over their feet.
  - Then, get them to reach over and try to touch a wall etc. that is far away from them, without moving their foot. In attempting to reach over, they will counter their balance by raising their other leg – explain that this restores their centre of balance.

1.2 Newton's Cradle

STORY:



EQUIPMENT/PROPS:

1. Newton's Cradle
2. *(optional)* Toy cars / Balls of different sizes

SCIENTIFIC CONCEPT(S):

1. Energy (Kinetic and Potential)
2. Conservation of Momentum and Energy
3. *(Advanced)* Momentum

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "How many balls will fly up?"**
    - Lift up 3 balls so there are only 2 balls remaining. When only 1 ball is released, it will stop upon contact with the 2nd ball, which will fly (similar to Newton's Pendulum).
    - Lift up two 2 balls and release them at slightly different times
    - Lift up 1 ball on each side and release them together
    - Lift up and release 3/4 balls

      ***Be careful when the kids play with the contraption as it can get tangled very easily**

- "**What are the different types of energy in this system?**" Explain kinetic and potential energies.
    - "**If I lift the first ball higher, will the last ball fly higher? Why?**" Explain the conversion of potential to kinetic energy.

- "**If I lift 2 balls up, how many balls will fly out?**" Explain the conversion of potential to kinetic energy.
    - *(Advanced)* "Can 1 ball fly up at twice the height?" Explain that it is not possible, as both kinetic energy and momentum has to be conserved.

- **"What determines kinetic and potential energy?"** Potential: Height and mass / Kinetic: Speed and mass. Can explain using toy cars to represent real vehicles, and come up with scenarios to determine the effect of each variable.

- "**Why do the balls eventually stop swinging?**" Explain the conversion of kinetic energy to sound and heat energy, and that no energy is created or destroyed.

Station 2 - Musician Stein

2.1 Instrument Pipe

STORY: Musician stein recently found a keen interest in music, so his mom-stein bought him the latest instrument - *drumroll*... It's a pipe with no instructions? How can he use this pipe to play a nice sound?

EQUIPMENT/PROPS:

1. Washing Machine Pipe *(refer to picture)*
2. Plastic Bag

SCIENTIFIC CONCEPT(S):

1. Sound (Amplitude ie. Volume; Frequency ie. Pitch)
2. Doppler Effect

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "How can I make music with this pipe?"**
    - Let the students try making sounds with the pipe, and guide them until they start to spin the pipe
    - Once everyone has a chance to spin the pipe, commence the explanation
      (!!) Safety Note: As the pipe will be spun around , there is a risk that it may hit others and cause injury. Ensured sufficient space for the demonstration to take place, and that students are closely supervised.

- **"Why does spinning the pipe make the sound?"** Let the students guess, but if they are stuck, move on to the next portion and ask them to observe and make logical guesses.
    - *(Advanced)* Ridges in the tube facilitate vortex shedding when air flows past them, resonance occurs when shedding frequency = natural frequency of pipe → sound produced

- **"What happens if I block one end of the pipe?"** Demonstrate that no sound will be created. Explain that the sound is caused by the air flowing through the pipe, striking the regular ridges of the pipe. Conversion of kinetic energy of arm -> kinetic energy of air -> sound energy.
    - **"What happens if I tie a plastic bag to the stationary end of the pipe?"** Show that the plastic bag will shrink due to the flow of air

- **"What happens when I swing the pipe faster?"** Explain that the greater speed leads to:
    - More energy: Louder sound
    - Faster airflow through the ridges: Higher pitch
    - Analogy of waves by the beach - how often the wave strikes, and how strong the wave is

- Carefully spin the tube horizontally above you, and explain the Doppler effect: sound waves being "compressed" and "stretched" due to your relative motion to the sound wave, causing the change in pitch. Real life example: Ambulance or e-scooter blasting music.

2.2 Laser Light Show

STORY: Having mastered the instrument pipe, Musician stein wants to have a concert. With these tools, how can he make a dazzling laser display as a fitting backdrop?

EQUIPMENT/PROPS:

1. Laser Pointer
   (!!) Safety Note: Students will NOT be allowed to use the laser pointer in case they shine it into others' eyes. Laser pointers will be safekept with student facilitators at all times.
2. Rubber Membrane with mirror attached

SCIENTIFIC CONCEPT(S):

1. Conservation/Conversion of Energy

RECOMMENDED FLOW OF EXPLANATION:

- **(DEMO) "How can I make a dazzling laser show with this tube?"**
  - Let the students vocalise their ideas on how to make a laser show
    (!!) Safety Note: Do not let students handle the laser light
  - Dim the lights and point the laser into the mirror to reflect it onto a wall. Sing into the tube and the laser light will form interesting patterns on the wall. "Do Re Mi Fa..."

- "**Why does singing cause the laser pattern to form?**" Direct their answers towards "vibration", and explain how sound is a form of energy as air molecules are being vibrated in their place.

- "**What are the types of energy in this system?**" Explain that sound is created by our vocal chords, which creates vibrations in the air passing through – get students to touch their throat as they talk or sing. Conversion of sound energy -> kinetic energy of vibrating rubber

- **(ACTIVITY) "What shapes can I create by singing different notes, or saying different words? Will different people singing the same note produce the same pattern?"**
  - Let the students try singing into the tube and seeing the pattern that comes out. Get each student to sing the same song / note, and see whether the same pattern appears.

Station 3 - Miner Stein

3.1 Bead Fountain aka. Self-Siphoning Beads

STORY: Miner Stein comes back home with a massive bucket of gem beads. He needs to obtain the beads from the bucket, but he can't flip the bucket or carry the entire weight of the beads. How can he do so?

EQUIPMENT/PROPS:

1. Plastic container
2. Long string of beads

SCIENTIFIC CONCEPT(S):

1. Gravity
2. Tension
3. Turning Radius *(intro to Centripetal Force)*

RECOMMENDED FLOW OF EXPLANATION:

- **(DEMO) "How can we get all these beads out of the container?"**
    - Let the students suggest how to get the beads out without tipping the bucket over - give any excuses for their answers that are not the "correct" answer. Once they suggest the "correct" answer, get 1-2 students to help perform the demonstration and everyone else to move back.
    - Lift up the container as high as possible for maximum chance of success, but ensure the students can still see - ask them to watch the mouth of the bottle carefully.
    (!!) Safety Note: Do not let students play with the beads

- **(DEMO) "At what speed were the beads falling to the ground?"**
    - Drop the empty container from different heights and observe the volume as an indicator of speed, to illustrate the effect of gravity. Explain the concepts of gravity and acceleration.

- **(ACTIVITY) "What is tension?"**
    - Line up the students in a row, and get them to extend their arms and interlock 1 finger.
    - Pull on one end of the human chain, and ask if the last person in the chain can feel the tug. "If the chain is 100 people long, will the last person feel the tug?" - unlikely, as energy is lost within the "material". Try out different configurations of the human chain ie. U-shaped chain
    - Explain that as gravity pulls down on one end of the string of beads, the end within the container is being pulled up by tension at an increasing speed.

- **(ACTIVITY) "Imagine you're in a car turning right - similar to the beads. Where does your body lean towards?"**
    - Maintaining in their row, get the students to sit down and close their eyes. When turning the vehicle, ask the students to imagine which side they will tilt towards.

- "**Why did the beads fly?**" Explain that as the beads "round the corner" at a faster speed, their turning radius will widen. This is why vehicles slow down when they make a U-turn, or else they will risk running out of road and into the street.

3.2 Centripetal Bottle

STORY: Miner-stein chances upon a bottle with an expensive gemstone trapped within. However, he is too small to lift the bottle up. How can he extract the precious gemstone?.

EQUIPMENT/PROPS:

1. Glass bottle with ball inside
2. Spring-loaded toy car (with string attached)
3. *(optional)* Tennis ball (with string attached)

SCIENTIFIC CONCEPT(S):

1. Centripetal Force

RECOMMENDED FLOW OF EXPLANATION:

- **(DEMO) "How can we get the marble out of the bottle without lifting the bottle?"**
    - Let the students try hands-on, but they will likely be unable to retrieve the marble. If they manage to do so not using the "correct" method, tell them that there is an even cooler, fool-proof method - adjust the ball to sit on the groove in the rod closer to the mouth of the bottle. On the floor, spin the bottle and the ball will fly out and reach the cork.
    (!!) Safety Note: Demonstration must be done on the floor to avoid breaking the glass.

- "**When we spin the bottle, why do the objects inside move?**" Use the previous analogy of a bus turning - when the bus turns left, you feel yourself turn to the right as it keeps you within the circular motion. If you're not resisting (i.e. a ball on the bus), it will roll around or topple.

- **(DEMO)** "**Can you push this car on a flat surface so that it travels in a circle?**"
    - **"What happens if we let go of this toy car while holding onto a string attached to its side?"** - Explain that the tension of the string attached to the car provides a force perpendicular to the car's motion ie. centripetal force.
    - "**What affects the centripetal force required?**" Experiment with different lengths of string and different speeds of the car. By isolating each factor, direct the students towards: mass, velocity ie. speed, and radius.
    - "**What provides the centripetal force required?**" Depends on the situation - tension of the string, friction with the surface, gravity, etc.

- **(TEST UNDERSTANDING)** "**Does it matter where we place the ball within the bottle? Does it matter which side we spin the bottle?**" Explain that centripetal force acts to the centre of the imaginary circle - each turning radius has its own imaginary centre point.

- "**Where else can you see this in real life?**" Moving vehicles, Lazy Susan, Merry Go Round - many situations involving circular motion!

Station 4 - Sleepy Stein

4.1 Faraday Cage

STORY: Sleepy Stein's radio has been possessed and he cant switch it off! He wants to sleep but the music is just too annoying!! How can we help Sleepy Stein to cut the music, if he can't switch it off?

EQUIPMENT/PROPS:
1. Metallic Cage
2. Airtight Plastic Box
3. Radio
   (!!) Note: Test the radio beforehand as some areas may have poor reception.
4. Metal Rod, Pencil, Wooden Chopstick

SCIENTIFIC CONCEPT(S):
1. Conductors and Insulators
2. *(Advanced)* EM waves

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "Will the plastic container or metal cage be better at stopping the music?"** Engage the students and run through their thought process, then try the plastic container first. Put the radio in and you should still hear music. Next, place the radio inside the Faraday's cage and it should start getting muffled. Based on their level of understanding, explain accordingly:
  - "**How do radios broadcast music?**" Signals are sent all over the island from radio stations *(can elaborate on EM waves for secondary school students)*
  - "**What happens when the radio is placed in the metal cage?**" Signals are disrupted as the cage conducts electricity, which "absorbs" the signals (by distributing the charge).
  - "**Why does the radio continue playing in the plastic container?**" Plastic is an insulator, which allows the EM waves to travel through

- **(ACTIVITY)** "**What happens if you touch the antenna with a metal rod / wooden chopstick / your finger / a pencil?**" Guide the students to conclude that our bodies are conductors of electricity because we are composed of 70% water, which is why it is also unsafe to swim during a thunderstorm. Also demonstrate that pencil lead conducts electricity, as it is made of graphite, one of the few non-metal electrical conductors.

- "**What are some real-life Faraday Cages?**" Lifts, Microwaves, Cars and Planes
  - Cars/Planes are not true Faraday Cages due to the large window openings - In order for a signal to be blocked, the size of the opening has to be on the order of 1% of the wavelength of the signal to be blocked - works for longer wavelengths like radio waves but not on microwaves used for phones. However, it does protect passengers from lightning!

4.2 Suction Mat

STORY: Sleepy Stein was busy experimenting with a new rubber material. As he tinkered with his experiments he fell into a deep slumber. A breeze blew into his window, and Sleepy Stein was feeling cold. Grabbing the nearest object as a blanket, he soon found himself stuck under this rubber mat! Help free him!

EQUIPMENT/PROPS:

1. Suction Mat ie. Rubber Membrane
2. *(optional)* Syringe

SCIENTIFIC CONCEPT(S):

1. Vacuum
2. Atmospheric Pressure

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "Who here can lift up this rubber mat with only the handle?"** Engage the students with a challenge - Let each student have a go. Soon the kids will realise that pulling it up by the handle is futile, while sliding/peeling it off is easy. They may give wacky explanations like friction and magnets - challenge their hypothesis by asking them to test it out eg. on the floor -> no magnet / on carpet -> doesn't work.

- "**Is there anything under the mat? Is there anything above the mat?**" Guide the students to realise that under the mat is a vacuum, while above the mat is the atmosphere.
    - "**Does air have mass? How heavy is the atmosphere? What does the atmosphere contain?**" Explain that that air has mass and the kilometers of atmospheres containing Nitrogen, Oxygen, Carbon Dioxide etc. weigh down heavily on everything! This surrounding atmospheric pressure acts upon the membrane and makes it almost impossible to pull it out - you need the equivalent of 8 horses (1000kg) to pull it apart. That is the power of 101 325 Pascal.
    - **(DEMO)** Seal one end of a syringe, and ask the students to pull the plunger - illustrates the idea of a vacuum. Explain that "high pressure exerts a push; low pressure exerts a pull" - the low pressure vacuum and high pressure atmosphere results in a net downward force.

- **"Why is it easier to lift the rubber mat by pulling up from the side?"** Air can rush in so that the air pressure is equal on both sides, thus it is much easier to pull the membrane.

- **(TEST UNDERSTANDING)** "**Why can I pull the rubber mat off the carpet floor so easily?**" Hopefully, the students will be able to explain that there is no vacuum created with the carpet floor.

Station 5 - Drenched Stein

5.1 Coke Float

STORY: Drenched Stein has accidentally started a fire in the lab and needs to get away safely. He realises that his lab is surrounded by water. But alas, he does not know how to swim! Fortunately, there are a few coke and diet coke cans lying around which he can use to get across. Which should he use as a boat to get across safely?

EQUIPMENT/PROPS:

1. A large transparent container of water
2. A can of Coke, Coke Zero, Coke Light (plus any other canned drinks)
   (!!) Note: During set-up, use a rubber band to tie 2x 50 cent coins to each can to ensure the experiment works. Ensure the students do not open the drinks, or make a mess by splashing the water.

SCIENTIFIC CONCEPT(S):

1. Density
2. Principle of Flotation ie. Archimedes' principle *(intro - build up to Cartesian Diver)*

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "Which cans will float, and which will sink?"** Present 3-4 different canned drinks for the students to guess from. Place the cans in the water one by one - drinks with "no or less sugar" should float, while the rest sink.
  - Get the students to look through the nutritional information on the back of the cans to figure out the difference between Coke and Coke Zero
  - Explain that most sweet drinks use sucrose or high fructose corn syrup, whereas "zero sugar" beverages use artificial sweeteners like aspartame or sucralose. These flavourings are man-made additives that bind to our taste receptors and to give a sensation of flavour, and very little artificial sweetener is needed to sweeten the drink (1:400)

- **"Which can is denser than water?"** Explain that cans that float in water are less dense.

- "**Can you explain what density is?"** To help them along, give the analogy of density = "squeeziness", isolating the factors of mass and volume:
  - MRT train, peak vs off peak hours: same volume, different mass
  - 100 passengers, MRT vs LRT: same mass, different volume
  - **(TEST UNDERSTANDING) "What is most dense? Solid, Liquid or Gas?"**

- **"What is the force helping the can to float?"** Explain that a floating object displaces a weight of fluid equal to its own weight (ie. Archimedes' principle), as it pushes away a certain amount of water, and the water pushes back on it.
  - **"What about objects that sink?"** Explain that they experience a similar amount of buoyant force in relation to their volume, making them appear lighter in water (draw parallel with swimming underwater), but is insufficient to let them float.
  - Where appropriate, tell the story of Archimedes running out of the bathtub naked,

5.2 Cartesian Diver

STORY: Instead of jumping onto a diet coke can, Drenched Stein decided to jump into a filled coke bottle and sank to the bottom. Quickly figure out how to send an oxygen tank to the bottom of the bottle to reach Drenched Stein before he drowns!

EQUIPMENT/PROPS:

1. 1.5L bottle full of water
2. Ketchup Packets / Sealed half-pipettes filled with colored dye
   (!!) Note: Test the ketchup packets beforehand - they should just float in a bucket of water

SCIENTIFIC CONCEPT(S):

1. Compressing States of Matter
2. Principle of Flotation ie. Archimedes' Principle

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "How can we get the ketchup packet to the bottom of the bottle?"** Let the kids try it out. If they are unable to figure it out, intrigue them by squeezing the bottle with one hand and following the descent of the packet with a finger as if performing a magic trick with the packet following the "enchanted" finger.

- **(DEMO) "What happens when the bottle is squeezed?"** Use the pipettes with dyed water to show the water level rising within the pipette when the bottle is squeezed.
  - "**Does the water compress? Which states of matter can be compressed?"** Explain that water is almost incompressible, and instead, air in the ketchup packet is being compressed. This makes its volume smaller and displaces less water, but its mass remains the same. With less water pushing it up, the ketchup packet sinks ie. Archimedes' principle.

Additional Experiments (Carnivals & Special Events)

(!!) Note: These demos explain slightly more complex concepts, so gauge the level of explanation based on the participant.

A.1 Polariser

EQUIPMENT/PROPS:

1. Polariser (2x)
2. Device with a white screen
3. Clear plastic objects (eg. Ferrero Rocher box cover)

SCIENTIFIC CONCEPT(S):

1. Light Waves
2. Polarisation

RECOMMENDED FLOW OF EXPLANATION:

- **(DEMO) "Can you see me through this?"** Demonstrate how the polariser works by putting 2 polarisers together and asking if participants can see you (YES!). Rotate one of the polarisers and ask them if they can still see you (NO!).

- "**What do you understand about waves? Did you know that light is a wave, but in many directions?**" Explain how light is a transverse wave (think of water waves, or waves on a string), The polariser only allows light travelling in a certain way to pass through. A polariser placed in the horizontal direction may allow light travelling horizontally to pass through, but not light travelling vertically. When 2 polarisers are placed perpendicular to each other, light travelling in one way can pass through the first polariser, but is blocked by the second one.

- **(DEMO)** Place a clear plastic object (plastic knife, Ferrero Rocher case etc.) on the device showing a white screen, then place the polariser over the object. The participant should see rainbow colours on the plastic object.

- **"What do you see? Why did the white screen end up producing so many colours?"** When plastic is produced in a factory, different parts of the piece of plastic have different thicknesses and stress, so light passing through them behaves differently (travels at different speeds ie. diffracts). With polarised light, we can observe the differences in optical qualities!

A.2 Diffraction Grating

EQUIPMENT/PROPS:

1. Red Laser
   (!!) Safety Note: Laser pointers will be safekept with volunteers at all times.
2. Diffraction Grating

SCIENTIFIC CONCEPT(S):

1. Light as a Wave
2. Diffraction

RECOMMENDED FLOW OF EXPLANATION:

- **(DEMO)** Shine a laser onto the table and ask how many red dots there are on the table - answer is 1. Now put the diffraction grating against the laser and ask how many red dots there are on the table - answer is 3 or 5, depending on lighting conditions. Also observe that there are clear bright dots and dark patches.

- "**How did 1 ray of laser split into 3 or 5 different rays**?" Diffraction. Light is actually a wave which can bend around obstacles, and all waves diffract when they encounter an obstacle or an opening.
  - **"What are some examples of waves?"** Water waves, sound waves, microwaves. Imagine you're in your room, and you can hear your parents nagging from the hall or kitchen even if you cannot see them. This is because sound is a wave that can "curve around obstructions" ie. diffract - even if the walls are sound-proof.
  - **"Look closely at the diffraction grating - what do you see?"** Notice that the grating will state XXXX lines/mm, and is actually composed of many small lines so narrow that we cannot observe them. When light passes through the gaps in these lines, it splits up and causes the different dots to appear.
  - **"Are all the dots the same brightness?"** Show that the dots get dimmer further from the centre, and that there are always an odd number of dots. Explain that the more a wave diffracts, the more energy it loses.

- "**Won't light diffract through all the holes in our surroundings, such as gaps in the door or windows?**" The diffraction grating has thousands of lines per mm, meaning that the gaps between these lines are very very small. Waves can be measured in terms of their wavelength - the wavelength of visible light is very small (much smaller than the width of a strand of human hair!). Hence, only very small slits can cause it to split up and diffract. Whereas, the wavelength of sound is 3-10m.

A.3 Quinine Lightsaber

EQUIPMENT/PROPS:

1. UV Laser
   (!!) Safety Note: UV laser will be safekept with volunteers at all times.
2. Bottle of tonic water, Bottle of clear carbonated drink

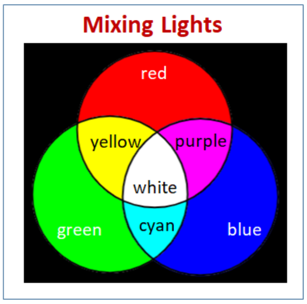
SCIENTIFIC CONCEPT(S):

1. Diffraction
2. Luminescence

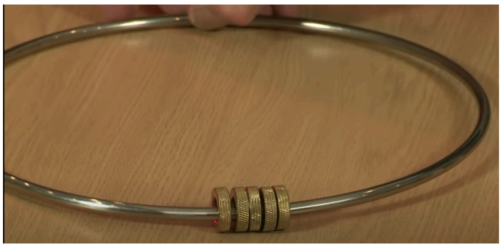
RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "Can you help me identify which one is tonic water, and which one is 7-Up?"** Pass the participants two transparent 500ml bottles - one containing tonic water, and another containing a clear carbonated drink - and they will try to guess which bottle contains tonic water. Visually examining and physically shaking will not yield any result, and DO NOT let them open the bottle to smell or taste.

- **(DEMO)** Shine the UV light into both bottles, and observe that one bottle causes the "lightsaber effect".
  - **"What is the difference in ingredients in both drinks?"** Direct them towards finding quinine, and explain that this is a special chemical that causes the effect.
  - **"What is this UV laser?"** Help participants to understand the concepts of:
    (!!) Safety Note: Do not let participants handle the UV laser.
    - UV: Like visible light, UV is an EM wave. It is invisible to the human eye, contains more energy than visible light, and causes sunburns.
    - Laser: Actually an acronym for *Light Amplification by Stimulated Emission of Radiation*. When an electrical charge is applied, particles are excited and reach a higher but unstable energy level. To return to their normal energy level, energy is released as visible light.
  - **"What colour is the UV laser?"** Any light, like the laser, is often made up of a few other colors - but mixing light works differently than mixing colours of paint.
  - **"Now, does the quinine absorb the UV light?"** Quinine absorbs invisible UV energy, which makes it excited, and then it releases visible light as it returns to its normal, unexcited state.



A.4 Ring on Ring



EQUIPMENT/PROPS:

1. Gyro Ring Toy

SCIENTIFIC CONCEPT(S):

1. Friction and Contact Force
2. Conservation of Energy

RECOMMENDED FLOW OF EXPLANATION:

(!!) Note: This is a mostly visual demonstration as the explanation is too complicated

- **(ACTIVITY)** Show participants how to spin the gyro ring toy, and guide them in spinning it for themselves. Make it interesting by trying out different techniques (e.g. using one hand, changing directions etc.)

- The main concept is that the large amount of **friction** between the small rings and the large metal ring **provides the energy required to keep the small rings in motion** without slipping down the ring.

- *Refer to: https://www.youtube.com/watch?v=DP86woa8Ue0*

A.5 Resonance Bowl & Glass

EQUIPMENT/PROPS:

1. Resonance Bowl
2. *(optional)* Wine Glasses

SCIENTIFIC CONCEPT(S):

1. Oscillation
2. Resonance

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY)** Unveil the resonance bowl and invite participants to make a sound with it – most of them will hit the resonance bowl with the rod. Volunteers will then press and rotate the rod along the outer rim of the bowl, **producing a sound that is of the same tone (frequency), but the sound gets louder and is sustained.** Guide the participants on how to produce this resonating sound.
    - **"How is the bowl creating the sound?"** Invite the participants to feel the bowl vibrating as it creates the sound, and explain that all sound is because of air particles oscillating ie. vibrating
    - **(ACTIVITY)** Where possible, get participants to line up at a fixed distance from one another, and rock from side to side – explain that their rocking is like air particles oscillating and transmitting the sound waves, and explain the concepts of amplitude and frequency.
    - **"When I strike vs. rub the bowl with the rod, do they produce the same sound?"** Guide participants to realise they are the same pitch, just of different volume. This explains the concept of natural frequency – the frequency at which a body tends to oscillate at, which is affected by the material, mass, shape etc.
    - **"Why does the sound get louder and louder? Am I rotating faster and faster? What happens if I rotate faster/slower?"** Rotating faster or slower than the natural frequency will cause the sound to be softer. Whereas, rotating at the natural frequency will cause the sound to be louder because of resonance. Give the example of the soldiers marching on a bridge at its natural frequency causing it to collapse in WWI.

- **(ACTIVITY) "What is the relationship between the water level, shape of the glass, and the pitch of the note produced?"** Allow participants to play around with the different glasses.
    - Students will realize that they need to dip their finger in the glass of water to moisten it before rubbing it along the edge of the glass to produce a sound. The **water provides a 'cushion' that reduces the friction between the finger and the rim**, allowing for slight vibrations of the glass that produces a note. **The vibration can be observed from patterns on the water surface.**

A.6 Cup Flyers

EQUIPMENT/PROPS:

1. Disposable Cups (Plastic/Styrofoam/Paper)
2. Rubber bands

SCIENTIFIC CONCEPT(S):

1. Magnus Effect

RECOMMENDED FLOW OF EXPLANATION:

This interactive station will allow students to make their own cup flyers, learn the science behind their cups 'flying', and get to bring their cup flyers home.

- **(ACTIVITY)** Where possible, let participants make their own cup flyer (alternatively, use a ready-made demo set): Tape the base of 2 styrofoam cups together. Make a rubber band string by tying 4 rubber bands to each other. Coil this rubber band around the centre of the 2 cups and releasing it will make the cups fly.
  - The direction of orientation of the cups, direction in which the rubber bands are coiled, materials and sizes of the cup affect the flight of the cup. Students will be able to play with cup flyers made from a variety of materials such as plastic, styrofoam and paper and a variety of sizes. Volunteers will guide them to formulate a hypothesis on the effect of the cup material and size.

- **"Who plays football or softball? Have you heard of the art of curving the ball such that they unpredictably swerve in the end?"** Explain that this phenomenon is known as the Magnus Effect, where the spinning ball causes the air around it to swerve, which leads to differences in air resistance and pressure on the two different sides of the ball, ultimately causing the ball to swerve.
  - The Cup Flyer helps illustrate the Magnus Effect through the way that the rubber band is coiled. When the cups are oriented horizontally, the rubber band unwinds in a way that causes the cups to swerve upwards. When the cups are oriented vertically, the rubber band unwinds in a way that causes the cups to swerve right.

- *As this is a highly visual experiment, it is better explained with a video: (https://www.youtube.com/watch?v=05zF0sBwHe8)*

A.7 Free Fallin'

EQUIPMENT/PROPS:

1. Soccer Ball, Tennis Ball
2. Notebook

SCIENTIFIC CONCEPT(S):

1. Gravity
2. Air Resistance

RECOMMENDED FLOW OF EXPLANATION:

- **(ACTIVITY) "Soccer vs. Tennis ball - which reaches the ground first?"** Participants will then drop the soccer ball and tennis ball at the same time - both fall to the ground at the same time. Explain that gravity is a force which pulls all objects to the ground, which is why we fall back down to the ground when we jump.
    - Tell the story of Newton discovering gravity when an apple dropped on his head

- **(ACTIVITY) "A sheet of paper vs. A notebook - which reaches the ground first?"** Participants will then drop the sheet of paper and notebook at the same time -the sheet of paper takes a longer time to fall.
    - **"What is slowing down the sheet of paper?"** We all know that air is around us - During strong winds, we feel something pushing against us and hindering us from moving forward. The air resistance felt by all falling objects is similar, and is dependent on its surface area. Both the notebook and the sheet of paper have the same surface area, so they experience the same upward air resistance; However, the downward force of the paper's weight is much less, to the point where the resistive force due to air resistance is significant - in most situations, air resistance is negligible, but it becomes more pronounced at greater surface areas (eg. skyscrapers) and higher speeds (eg. F1 cars). This concept can also be seen in nature - birds spread out their wings so the increased upward air resistance enables them to glide without flapping their wings.

- **(ACTIVITY) "A sheet of paper below the notebook vs. above the notebook - any difference?"** Participants will perform both demonstrations in sequence, and realise that in both situations, they fall together. Explain that the notebook pushed away the air below it, hence the sheet of paper is not experiencing any air resistance.

- **(TEST UNDERSTANDING) "A sheet of paper vs. crushed ball of paper - which reaches the ground first?"** Get the participants to try explaining why the paper ball falls faster - hopefully, they are able to recall that the larger the exposed surface area, the larger the air resistance.

Sequence of Events for Small-Group Programme

No. of Children: ~25 (5 groups of 5)
No. of Group Facilitators: 10 (2 per group)
No. of Station Masters: 5 (1 per station)

Roles and Responsibilities	
Group Facilitators ***(you!)***	**Station Masters** *(core team/senior volunteers)*
• Befriender • Explain science	• Timekeeper • Storyteller • Fill in science explanation

Duration: 2 hours

Time	Activity	Remarks
10 min	Introduction by OT	OT will explain the storyline and the aim of the program
15 min	Announcement of groups, Ice breakers	Participants are pre-sorted (by age) into groups of five Introduction of Mini-stein personas
80 min	Round-robin stations	• 15min x 5 stations + 5min buffer = 80min • 20min x 4 stations = 80min
15 min	Debrief by OT, Photo Taking	OT will wrap up the storyline and consolidate the learning objectives; If time permits, conduct 1 last demonstration for the whole group.

Other Admin Matters

1. Links

Schedule: tinyurl.com/einsteinschedule
Post-Event Form: tinyurl.com/einsteindone

Do get your friends to sign up too!
Info Slides: tinyurl.com/opeinsteininfo
Sign-ups: tinyurl.com/einsteinsignups

2. OT Contact Details

Name	Email	Contact Number
Phebe Lew Yu	operationeinstein.ri@gmail.com	8367 6616
Matthew Yar		9867 3436
Pan Yifan		8457 7639
Anika Lee		9878 3078
Anushka Daga		8497 9207
Shira		9181 9042

3. VIA Hours

3.5 hours will be awarded for each small-group session, and 5 hours will be awarded for each carnival session. However, some carnivals and ad-hoc events have different durations, and the hours will be awarded accordingly.

VIA hours will only be keyed into the system in May, and will thus **not be reflected in your progress report this year**.

For RGS volunteers, VIA hours will only be keyed into the system after you enter RI (Y5-6). The hours awarded when you are in Y3&4 will be accumulated, and your total hours from Y3 to Y6 will be reflected together. **Hours from Einstein will not appear in your RGS progress report**.

Do contact the OT regarding any queries.