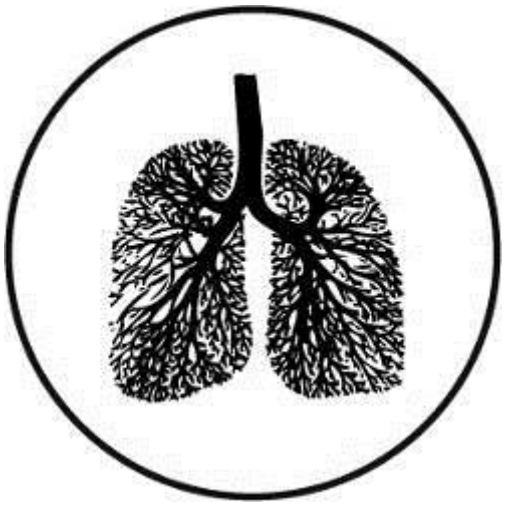
ENGINEERing challenge workshop for science museums in the field of Biomedical



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ENGINEERing challenge workshop in the field of Biomedical

Workshop ID card

Name of the workshop: How can we measure the volume of an inflated balloon? From a medical problem to an engineering solution

The Challenge: Measuring the volume of air in a balloon that simulates the volume of air that a girl can expel after a deep inhale.

The Engineering field: Biomedical engineering

The science field: Respiratory system, measuring volume

Target audience: Families with children from the age of 8 and / or pupils in the 4-6th grade

Type of activity: Workshop

Duration of activity: 45 – 60 minutes

Specific notes: It is recommended to operate this workshop in a space that can get wet and has running water.

Context

The workshop ***How can we measure the volume of an inflated balloon?*** *From medical problem to engineering solution* will broaden participants' awareness on how engineers work. In this workshop we will specifically look at biomedical engineering through a relevant scenario which will give the participants a challenge of developing and designing a biomedical instrument for measuring exhalation volume. The participants will **Ask** and gather information through scientific experiments and then, working in small groups, each group will **Imagine** some solutions, **Plan, Create** and **Improve** its own solution.
The specific science aspects that will be taught in this workshop are the respiratory system and measuring volume.

Maximum number of participants: up to 20 (4-5 groups)

Number of facilitators (intern): 1

Location: a space that can get wet and has running water. There should be a central table on which to place all the resources, a table used for the instructor's demonstrations and seats around table/s for all the participants.

Set up time needed: 30 minutes

General objectives:

The ENGINEER Museum Activities:

- ✓ Offer the participants to find and experiment different solutions to solve a "real" engineering problem.
- ✓ Give a new perspective on Engineering as a field, a process, a way of thinking and working.
- ✓ Introduce and exemplify the EDP (Engineer Design Process: Ask, Imagine, Plan, Create, Improve), or part of it.
- ✓ Give the participants the possibility to reflect on what they have done and how the Engineers work.
- ✓ Are based on IBSE - Inquiry Based Science Education and are not gender oriented.

Specific unit objectives:

The biomedical ENGINEERing workshop:

- ✓ Provides the opportunity to plan and create **a biomedical instrument** for measuring volume using the Engineer Design Process.
- ✓ Teaches that **air** is a substance that takes up space and that this space is called **air volume**.
- ✓ Teaches that **maximal exhalation volume** is the largest volume of air that can be expelled from the lungs after deep inhalation and gives the opportunity for each participant to measure it.
- ✓ Emphasizes the importance of some factors as accuracy, reliability and ease of use for **measuring instruments** and encourages the participants to apply at least one of them.

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Resources (for 20 participants):

Material	Total amount	Expendable	Non-expendable
Balloons inflated with about 200 ml air (Can be done by pressing twice on a balloon pump) 	10		

Material	Total amount	Expendable	Non-expendable
Regular balloons	10		
Plastic bags 	40		
Water – 1½ litre bottle	5		
Drinking straws	3		
Cards 	20		
Sellotape	1		
Plastic cups (200 ml)	2		
Baking soda	1 tsp.		
Full water bottle– 1 ½ litre	5		
Pencils	5		
Bowls (8-10 litre)	5		
Calibrated measuring cups used in the kitchen etc. 	2-4		

Material	Total amount	Expendable	Non-expendable
Familiar food containers or plastic bags marked with their volume (milk bottles/plastic bags, soft drink bottles, cleaning materials, oil etc.)			
1 or 2 litre measuring tubes 	3		
50 ml measuring tubes	5		
60 ml syringes	20		
Permanent markers	5		
Garden faucet connector with valve + hose 	5		
Full cylinder/sealed bottle, same circumference as measuring tube 	5		

Material	Total amount	Expendable	Non-expendable
Flexible plastic tube, 30 cm long, diameter 1 cm. 	2-3		
*Thread (20 cm)	5		
*Calculator	5		
*Formula sheet (circumference of ball and volume of ball)	5		
Clips 	5		
Draft papers	10		
Scissors	2		
Rulers	2		
Eraser board	1		
Board marker	1		
Spray bottle containing 70% alcohol	1		
Funnels (5-10 cm diameter)	2		
Soft drink bottle with hole	2		
wide tubes (diameter 3-4 cm) + narrow tubes (diameter 4-5 mm) 4-5 cm long 	3		

Material	Total amount	Expendable	Non-expendable
Plastic sleeve + spout 	20		
Flexible plastic seals for syringes 	20		
Wide pipe (2-3 cm diameter)	3		
Balloon pump 	1		
Poster of EDP	1		
Tables	1 central + 1 long with 20 seats or 5 with 4 seats		
Chairs	20		

The workshop

Introduction - defining the medical problem and presenting the challenge – 2-5 minutes

Welcome the participants and tell who you are. Tell them that today they will work like engineers – they will solve a challenge in a similar way as real engineers called Engineer Design Process.

The facilitator will tell the participants in brief, in his own words, the story: ***How can we help Yael? Surprising challenge on the annual school trip*** *(you can find the full story in the appendix)*.
Yael suffers from breathing difficulty. Whenever she exerts herself (runs, practices judo or plays games) the problem is worse. Her shortness of breath is more severe in the spring, on days when there is a lot of dust in the air, after a bonfire, when going downtown (air pollution caused by vehicles), or when visiting her uncle, who is a heavy smoker. Yael went to the doctor and she told her that in order to know exactly what she suffers from *(to diagnose her medical problem)*, there is a need to do some measurements of her lung function *(where are our lungs located? What is in them?)*. She gave her a biomedical instrument for measuring exhalation volume and ask her to measure once a day her maximal exhalation volume= the largest volume of air that can be expelled from her lungs after deep inhalation. After 2 days, Yael went to her annual school trip, and took her measuring instrument with her. At night, before she went to sleep, she opened her bag, in order to take out her measuring instrument but… she discovered, to her horror, that the measuring instrument was broken. She asked her friends to help her to find a method or design an instrument to measure her maximal exhalation volume with the resources they have in the camp. Her friends succeeded!

In this workshop, your challenge is to measure the volume of air in a balloon that simulates Yael's maximal exhalation volume.

Tip to the facilitator - write the challenge on the board, either now or at a later stage.

Before we tackle the challenge we will do a few experiments to obtain information that may help us to find a solution.

Tip to the facilitator - for family workshop, you can assume that the parents already possess some of the information, so it is advisable to set limits by telling the group that the experiments we will carry out in the next 5 minutes are mainly designed to provide information for the children (and are less relevant for adults).

The main activity – 35- 40 minutes

What is air? Is it material? Does it take up space (does it have volume?) – 5-10 minutes

- **Inflating a balloon in a bottle - Demonstration with 2-4 participants**
  You need 2 transparent bottles with balloons, and a hole in the bottom or side of each bottle. Cover the hole in one bottle with transparent tape. Ask two children to try to inflate the balloons.
  Why can one child inflate his balloon while the other cannot?
  Listen to the children's answers. Invite other volunteers to try to inflate the balloons.
  How do we test and verify the explanations?

Try to implement their suggestions. Finally, uncover the hole in the second bottle and try again to inflate the balloon. At this stage, relate to answers that focus on the fact that the air takes up space.

Explanation: the air in the balloon is a material that takes up space. When the hole is sealed there is no place for the air around the balloon to escape, so it is more difficult to inflate the balloon. When the hole is uncovered we can inflate the balloon because the air around it is pushed out through the hole.

- **Compression of air in a syringe - Self-experience**

  The facilitator will give each participant a syringe and ask them to try compress the air in a syringe.

  What is volume?

  Volume is the space taken up by material (solid, liquid, or gas).

Becoming familiar with the concept of air (gas) and water (liquid) volume – measuring instruments and units of measurement – 5-10 minutes

- **Display various measuring instruments and containers with volume markings.**

- **A brief demonstration includes important principles of measurement:**
  - What units are used to measure volume? What is litre? What is a cubic centimetre?[1]
  - Is the volume of 50 millilitres in a measuring tube equal to 50 millilitres in a measuring cup? Demonstrate.
  - If you have to measure 50 millilitres would you do so in a syringe or in a 1 litre measuring tube? Demonstrate that every measuring instrument has its own range of measurement. We cannot use a ruler to measure the distance between Jerusalem and Tel Aviv, or the thickness of a sheet of paper, but we can measure the length of the paper. Similarly, if we want to measure 50 millilitres we can obtain a more accurate measurement by using a 50 ml volume measuring tube than by using a 1 litre measuring tube.

- **When planning a measuring device, what criteria must it adhere to?**
  - Accuracy: If you need to measure one and a half litres, would you prefer to use a 1½ litre bottle or a two litre measuring tube? To what extent will the means of measurement give you a result that is close to the exact volume of the container? If you have a measuring tube and you need an accurate measurement, you should use it. If your measurement does not need to be accurate and you don't have a measuring tube, you can make do with a 1½ litre container.
  - Reproducibility (repeatability): Does your method of measuring enable you to obtain the same result (or a very similar one) each time you measure? When you weigh yourselves at

[1] Litre – a measurement unit of volume equal to the volume of a cube with 10 cm sides. Cubic centimetre = 1 centimetre cubed. 1 litre = 10 centimeters^3 = 1000 cubic centimetres.

home, it is important that if you do so more than once (not necessarily before and after eating☺) the result will be the same.

- Easy to use: How simple and easy to use is the measuring method or device?
  - Can be used repeatedly (frequently/only once): Can your method of measurement be used more than once on the material to be measured, or can you only do it once? Demonstrate a disposable measuring device by using litmus paper – this paper measures the degree of pH of a solution (acidic or alkaline) – it changes colour according to the degree of acidity (red/pink litmus paper turns blue in an alkaline environment). Insert the paper into a cup containing a small amount of baking soda dissolved in water – the paper will change colour. If you insert the same paper into a cup containing water it will not change colour again – the paper can only change colour once.

Tip to the facilitator - The length of time depends on the group – the participants' level of knowledge and their interest. Small children may need 5-7 minutes while adults need less than 5 minutes. Participants are invited to suggest which criteria are important when planning a measurement device. If it is not appropriate to suggest criteria at this stage, you can refer to them when they present their solutions. It's recommended to write the criteria on the board.

The challenge – 20-25 minutes

- **Remind the challenge:** To find a way to measure the volume of air in a balloon that simulates Yael's maximal exhalation volume.
- **Give clear instructions**:
  - The first stage is to **Imagine** – to suggest solutions, at least two. Look at the materials on the table but do not take them without the instructor's permission. Participants should be reminded to relate to one or more of the criteria mentioned earlier with regard to measuring devices.
  - The second stage is to decide on one solution that meets one or more of the criteria that were raised previously (you may find that drawing a sketch can be useful).
  - The third stage is to **Plan** exactly what you want to do. We recommend that you draw it, but you can also write down the details. Show your sketch to the instructor, and then you will be permitted to take materials.
  - The fourth stage is to **Create** the device/instrument for measuring the balloon volume.
  - The fifth stage is for each group to present its device and the criteria which it answers.

Tip to the facilitator - The instructions should be accompanied by the poster showing the design process.

- **Each group takes the resources according to its plan**
  The following materials and equipment will be on the central table (exact quantities can be found in the resources section)
  - A balloon inflated with approximately 200 ml air, closed with a clip.
  - Additional balloons
  - Bowl

- Water – one 1½ litre bottle
- Wide measuring tube
- 500 ml measuring cup (wide)
- Four 60 ml syringes
- Plastic bags
- Permanent marker
- Garden faucet connector with valve attached to drip hose
- Cylinder or plastic bottle with the same diameter as the measuring tube
- *Thread
- *Calculator
- *Formula sheet (circumference of ball and volume of ball)
- Additional clips
- Draft paper
- Pencil

*Optional, could be useful for advanced pupils and adults

- **Working in groups, according to the stages outlined above** - approximately 15 minutes
  The instructor is available to provide assistance where needed.

- **Summary** 10 minutes
  The participants briefly present their solutions.
  The Instructor sums up and raises other possible solutions; Relates to the criteria that engineers also take into account when designing products; Mentions the failures – we don't always succeed, but we learn and improve (at home…); Refers to the stages of the design process that the participants went through, using the poster: The Engineer Design Process is how engineers work when solving problems. The stages of the process are not necessarily linear. At each stage it is possible to return to any other stage.
  Ask - Asking questions and gathering information.
  Imagine - suggesting ideas to solve the problem and choosing the preferred solution.
  Plan – planning and designing the chosen solution.
  Create – building a prototype.
  Improve - Testing, evaluating, and improving

What problem does Yael suffer from? 2-5 minutes

It appears that Yael's breathing problem is due to a condition/ illness called asthma, which many people suffer from. Asthma is not characterized by an unusual lung volume but by constriction of the bronchial tubes – the tubes that carry air to and from the lungs. During an asthma attack, the bronchial tubes that carry the air become narrow and it is difficult to draw air into the lungs, and especially difficult to expel the air from the lungs.
Brief demonstration by instructor – exhaling through a wide tube and a narrow tube
The facilitator takes a deep breath and exhales all the air at once – first through a narrow tube (drinking straw) and then through a wide tube. He asked the participants to measure how much time it takes to exhale the air through the narrow tube compared to the wide tube.

*You can ask all the participants to exhale air from their lungs when their mouth is wide open compared to doing so with pursed lips (like whistling). Which one is easier?

Conclusion – measuring maximal exhalation volume using calibrated plastic sleeves – 10 minutes

Give clear instructions for using the plastic sleeve:

1. Take a deep breath.
2. Exhale all the air into the plastic spout attached to the sleeve.
3. With one hand hold the sleeve closed and with the other "compress" the air into the end of the sleeve until you can't push any more.
4. Read the number marked on the gradations of the sleeve – this is your maximal exhalation volume.
5. Note the measurement on your card.
6. Take home your card as souvenir

Information for the facilitator

Background information about the respiratory system

The respiratory system is the system in the human body that enables us to breathe.
The act of breathing includes: inhaling and exhaling air in the body; the absorption of oxygen from the air in order to produce energy; the discharge of carbon dioxide, which is the byproduct of the process.

The parts of the respiratory system
The respiratory system is divided into two parts:

1. Upper respiratory tract. This includes the nose, mouth, and the beginning of the trachea (the section that takes air in and lets it out).
2. Lower respiratory tract. This includes the trachea, the bronchi, broncheoli and the lungs (the act of breathing takes place in this part of the system).

The organs of the lower respiratory tract are located in the chest cavity. They are delineated and protected by the ribcage, the chest bone (sternum), and the muscles between the ribs and the diaphragm (that constitute a muscular partition between the chest and the abdominal cavity).

- **The trachea** – the tube connecting the throat to the bronchi.
- **The bronchi** – the trachea divides into two bronchi (tubes). One leads to the left lung, the other to the right lung. Inside the lungs each of the bronchi divides into smaller bronchi, called broncheoli.
- **The lungs** – a pair of organs found in all vertebrates. The structure of the lungs includes the bronchial tree – air tubes branching off from the bronchi into smaller and smaller air tubes, each one ending in a pulmonary alveolus.

– **Pulmonary alveoli** – tiny sacs (air sacs) delineated by a single-layer membrane with blood capillaries at the other end. The exchange of gases takes place through the membrane of the pulmonary alveolus, which always contains air: oxygen (O_2) is absorbed from the air into the blood capillaries and the action of the heart circulates it through all the tissues in the body. At the same time, carbon dioxide (CO_2) is transmitted from the blood capillaries into the alveoli and then expelled through the bronchi and the upper respiratory tract.
The inner surface of the lungs where the exchange of gases takes place is very large, due to the structure of the air sacs of the alveoli.

The breathing process

The breathing process has two stages – inhalation and exhalation

- Inhalation – the intake of air into the lungs through expansion of chest volume.
- Exhalation – the expulsion of air from the lungs through contraction of chest volume.

Inhalation and exhalation involves muscles:

1. Rib muscles = the muscles between the ribs in the chest.
2. Diaphragm muscle

Muscle movement – the diaphragm and rib muscles are constantly contracting and relaxing (approximately 16 times per minute), thus causing the chest cavity to increase and decrease.

During inhalation – the muscles contract:

Contraction of the diaphragm muscle – causes the diaphragm to flatten, thus enlarging the chest cavity.

Contraction of the rib muscles – causes the ribs to rise, thus increasing the chest volume.

The chest cavity expands, thus reducing air pressure and causing air to be passively drawn into the lungs. Air passes from the high pressure outside the lungs to the low pressure inside the lungs.

During exhalation – the muscles relax:

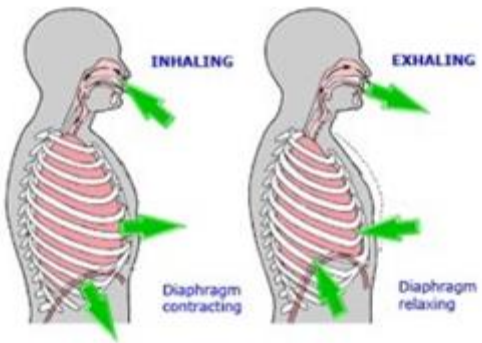
The muscles are no longer contracting, they are relaxed.

The diaphragm curves and rises, the ribs descend – and chest volume decreases.

The chest cavity contracts thus increasing air pressure and causing the air in the lungs to be expelled through the upper respiratory tract. Exhalation, too, is passive. Air passes from the high pressure in the lungs to the low pressure in the upper respiratory tract.

Inhalation and exhalation are involuntary and therefore their control requires an effort.

The breathing process – Illustration & Animation



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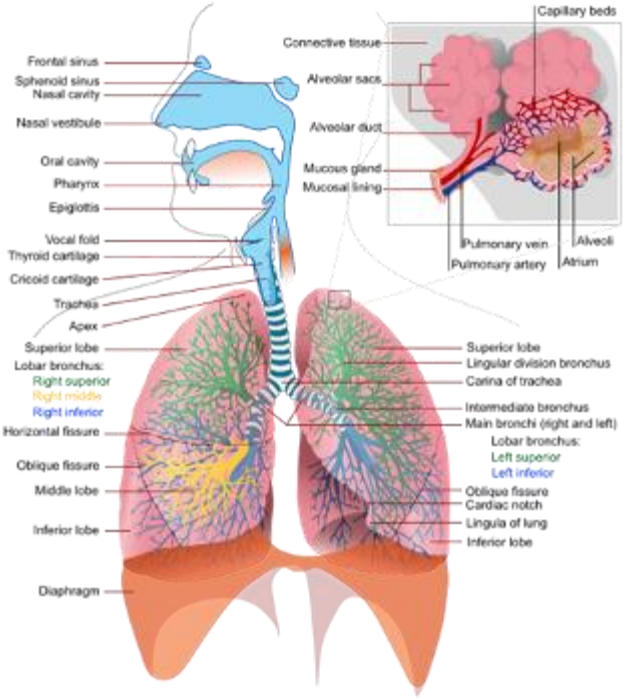
Wikipedia link to Animation that illustrates changes in chest volume during inhalation and exhalation – note that it only shows the movement of the diaphragm, not that of the rib muscles.
http://commons.wikimedia.org/wiki/File:Diafragma_ademhaling.gif

The respiratory system- Illustration



From Wikipedia:
http://upload.wikimedia.org/wikipedia/commons/5/5e/Respiratory_system_complete_en.svg

Tip – you can find more information about the respiratory system here:
http://www.mada.org.il/en/about/engineer/challenge/respiratory-system#functions

Background information about measurement

Units of measurement

Measuring devices are used for many purposes: rulers measure length, thermometers measure temperature, and scales measure weight. What they all have in common is the fact that the results obtained are in numbers: 10 centimeters, 35 degrees, or 100 grams. Some things cannot be measured accurately, but they can be assessed and compared. Examples are love, anger, even taste and smell. We love our parents more than our schoolteachers; ice cream tastes better than spinach or onion. Assessment and comparison are a type of preparatory stage to proper measurement. If we look at two children standing side by side we can tell which is taller. If we touch two objects we can tell which is warmer. But such assessments and comparisons cannot tell us accurate height or

temperature. Furthermore, if the children are not standing together, or if we do not touch the two objects at the same time, it will be difficult to compare them. Measuring devices tell us precisely what we want to know without being dependent on other objects for comparison. But in fact, nearly every measuring device and measuring process is based on comparison, not comparison between two objects but comparison with a standard size. A ruler measures length by comparison with a standard unit of measurement (for example, a centimeter), by 'counting' how many times the unit of measurement 'goes into' the length being measured. A thermometer 'counts' how many degrees 'go into' body temperature, and scales 'count' how many units of weight (for example, grams or kilograms) 'go into' body weight.

Basic and fundamental units of measurement include:

- Length, measured in millimeters, centimeters, meters and kilometers.
- Weight or force, measured in milligrams, grams and kilograms.
- Time (second, minute, hour…)

Some units of measurement are combinations of others.

For example, volume is measured in liters, cubic meters, or cubic centimeters. In other words, the volume equals the volume of a cube whose length is a meter or centimeter.

The most important aspect of measuring devices is their ability to repeat and reproduce results. In other words, each time we measure the same thing, we must obtain the same result.

Tip – you can find more information about measurement here:
http://www.mada.org.il/en/about/engineer/challenge/measurement?from=ref-inpage

Appendix – Story to set the context

How can we help Yael? Surprising challenge on the annual school trip

"Yael, you're next!"

Yael stood up and walked to the doctor's office, feeling slightly nervous. The doctor smiled and asked her to sit down.

"Hello, Yael, my name is Michal and I'm a doctor. I specialize in the respiratory system. How can I help you?" Yael was very surprised that the doctor was asking her questions instead of examining her.

"It all started two weeks ago," explained Yael. "We were playing ball during recess and in the middle of the game I started having pains in my chest. I had to stop playing to catch my breath, and when I inhaled, there were wheezing sounds in my throat.

"A few days ago," she continued, "when we were on our way to the grocery store a bus drove by emitting clouds of black smoke. Everyone started coughing, but I coughed more than anyone else."

The doctor listened carefully, and then said, "I understand that you have breathing difficulties. We'll have to find out what's causing them."

Yael was alarmed. "But I'm going on a school trip tomorrow. I don't want to miss it!"

The doctor smiled. "Don't worry, Yael. We just have to carry out a simple check, something you can do by yourself during the school trip. I can see that you're mature and responsible and I'm sure you can manage it."

That made Yael feels much less nervous. In fact she was quite proud that the doctor thought she was mature and responsible. "What do I have to do?" she asked.

"I'm going to give you an instrument to measure the maximal exhalation volume you can expel from your lungs, and I'll also give you a little notebook. Every day for a week I want you to take a deep breath and expel it as hard as you can into the measuring instrument, and then write down the result. We'll meet again in a week and you'll show me what you wrote in the notebook. The results can help us diagnose your problem."

That didn't sound scary at all. Yael took the measuring instrument and the notebook. "Don't worry, doctor," she said, "I'll record the results exactly like you said. You can count on me."

The doctor smiled again and said goodbye. Yael's mother was waiting outside. Yael showed her the measuring instrument and the notebook and explained what the doctor had told her to do.

* * * * * * * * * *

The next morning Yael woke up early to prepare for the trip. Of course she remembered what the doctor had told her. She packed the measuring instrument and the notebook, and she didn't forget to take something to write with so she could record the results. Then she hurried to school with her big backpack to show her friends her new measuring device. Just then the bus arrived and all the children climbed in. Yael quickly shoved the instrument on top of everything else and placed her bag in the large baggage compartment. Then she ran to find a seat next to her best friend Avigail.

* * * * * * * * * *

The trip was lots of fun. When they stopped, the guide asked everyone to take out their water bottles and drink plenty of water. But when Yael opened her bag to look for her water bottle she discovered, to her horror, that the measuring instrument was broken. It must have been squashed against the other bags while the bus was moving. Nearly in tears, Yael carefully took out the pieces, one by one. How would she measure her exhalation volume? The doctor would be so disappointed.

"Don't be upset, Yael," said Avigail, as all her friends gathered round. "We'll help you find a solution. Didn't you say the doctor wants you to measure your maximal exhalation volume? I'm sure we can find some way to do so, even without the instrument the doctor gave you."