# Playing with Pressure -Teacher Notes

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**Figure 1 – High-pressure steam locomotive**

**Aim**

Every living organism on Planet Earth, at sea level, experiences an atmospheric pressure of 101.325kPa which is equivalent to approximately a mass of air of 10,339 kg/m$^2$. Our bodies are designed to cope with this pressure, without which we would not be able to survive. The pressure inside our lungs and ears is the same as the atmospheric pressure surrounding us. This guarantees that we will not crush under the atmospheric pressure. Thankfully, our bodies are flexible enough to adapt to variations in the external pressures, of course within limits. At higher altitudes such as in an aeroplane, our ears pop during take-off or during landing, this is due to the difference in air pressure on either sides of our ear drums.

Pressure is defined as the force applied per unit area, it has many applications in our daily lives including sucking out of a drinking straw, syringes used to take blood for blood tests, vacuum cleaners, hydraulic pumps, climate control and much more.
In this experiment, students will have a chance to investigate situations involving pressure and how pressure acts in different scenarios. By the end of this experiment, students are expected to explain the physics underlying many phenomena involving pressure.

**Plan**

This experiment is suitable for students from year 7 to year 12. Different stages can use the experiments to gain hands-on experience on different aspects of their learning outcomes. The experiment involves three separate experiments, the teacher can either assign experiments to their students or allow students to choose which experiment they want to study. It is a good idea to allow students to watch a link on some experiments done using pressure at the following links: https://www.youtube.com/watch?v=YcrbtDQGk3s and/or https://youtu.be/axbFo-wsp4g .This will help students visualise the concept of air pressure and will assist them with making their hypothesis.

Before starting the experiments, make sure students know the risks associated with the experiment and how to avoid them. The first risk is with using the Bunsen burner. The student notes have a full description on how to use them. It is preferred that the teacher explains it in detail and light one as a demonstration, especially if students are inexperienced in using them. The teacher may also like to play a clip on how to light the burner on https://www.youtube.com/watch?v=N7ssCM3qM3U . This can be followed by giving the students a worksheet to answer about operating a Bunsen burner. Some links to worksheets are as follows: https://learning.bishops.org.za/science/wp-content/uploads/sites/17/2014/06/TheBunsenBurnerWorksheet.pdf
https://www.tes.com/teaching-resource/bunsen-burner-flames-worksheet-6355578
https://www.tes.com/teaching-resource/bunsen-burner-introduction-worksheet-3008315

The experiment also involves the use of glassware, in case of any glass breakage students should be aware to report all accidents to their teacher. Make it clear that they should wear safety gear, including safety glasses and gloves and to wear silicon hot hands or any other protective gloves while holding hot objects as well as tongs when holding the hot soft drink can.

**Conduct**

The experiment is a mix of prescribed, guided and open inquiry. Students are provided with the question and procedure, and they will be guided during conducting and recording. They will analyse their results, come to a conclusion and justify their findings.

According to the number of students, the laboratory will be prepared to equip three different experiments. Before they start, students are asked to write a hypothesis. This hypothesis should reflect the student's understanding of the principles. Conducting the experiment will then either support their hypothesis or the student will modify their preconceptions. Teachers may guide students with writing a good hypothesis by showing one or more of the clips provided, holding a class discussion or asking students to do research beforehand. Students should also be aware that sometimes the experiment does not support the hypothesis, not because the hypothesis is wrong but because the experiment was not conducted properly. This will build students' research skills and critical thinking.

The students are given a list of materials and a method to conduct the experiments.

1. ***Gas pressure on a balloon***

This experiment is suitable for stages 4 and 5 but it is very closely related to year 8 who study forms of energy and how they cause changes within systems. It can also be used as a demo to year 12 for the interconnection between pressure and volume in their study of Le-Chatelier's Principle in the chemistry course.

Here, students will place a balloon over the opening of a conical flask containing an amount of water which is heated slowly. They will then remove the flask from the heat, remove the balloon and re-attach it immediately and place the conical flask in ice water.

They will observe what happens to the balloon and write their observations.

***2. Can crush***

This is a demo of the effect of unbalanced forces on objects, suitable for all stages from 4 to 6. Students will add approximately 30 ml of water to an empty soft-drink can and heat it until they observe steam coming out consistently. They will then quickly flip the can over, submerging the opening in a cold-water tray and observe what happens. Students will write their observations.

***3. Fountain experiment***

Similar concept as experiment 2. Here, students will half fill a large beaker with cold coloured water. They will add 30 ml of clear water to a round bottom flask and place a rubber stopper with a glass tubing at the opening of the flask. They will then heat the water in the flask to the boil and invert it to submerge the glass tube in the coloured water in the beaker. They will record their observations over a period of 30 seconds.

***Extension***

The field of pressure is very exciting and the teacher can expand to help students learn about different parameters related to pressure such as volume, temperature, force and energy. There are plenty of experiments to be done as an extension or they can be added in the same laboratory as more stations. Groups studying the same concept can acknowledge each other's work in their presentations.

***Effect of differential pressure on motion of objects***

- Boil an egg and peal it.
- Fold a piece of paper into a fan, light it and place it inside a conical flask.
- Quickly place the boiled egg on the opening of the flask.
- Observe what happens.

***Air pressure is pushing in all directions***

- Boil an egg and peal it.
- Light two small candles and place them on the egg (same like when you put the candles on cakes).
- Invert the flask and put the opening over the lit candles on the egg.
- Observe what happens.

***For advanced classes – A challenge on how to get the trapped egg out of the flask***

- They should think of a way to fill the flask with air, such as blowing hard inside the flask.
- For this experiment use a small flask or a small glass bottle with a wide enough opening so that the egg does not break while entering.

**Analyse**

Students will write their observations and start analysing their results. It is easier to read and compare when the results are tabulated. Depending on the experiment, students can design their analysis table.

The teacher may like to draw or project a similar table with more cells on the board to include the results of all groups doing the same experiment for comparison and class discussion.

| | **Action done (students will write what they've done at each stage)** | **Action done (students will write what they've done at each stage)** |
|---|---|---|
| **Observations** | | |
| **Sketch of results** | | |
| **Explanation** | | |

**Problem solving and discussion**

Students will explain their results and mention whether their results agreed with their hypothesis. If the results disagree with the hypothesis, students can confirm if their hypothesis was wrong or identify if something went wrong during the course of the experiment.

1. ***Gas pressure on a balloon***
   In this experiment students will notice that the balloon inflates when the water is heated, and that it sucks in  when the flask is placed in the cold water.
   They should relate this to the kinetic energy of air particles and correlate this to the pressure exerted by the air particles.
   Air is composed of gas particles which we cannot see, yet these experiments can prove their presence. When these particles are heated they gain thermal energy. This energy is transformed into kinetic energy of the particles, which start to move more rapidly. This rapid motion causes the particles to collide more frequently, leading to more pressure on each other and on the walls of the balloon. This is why the balloon expands.

When the flask and its contents are cooled (cooling is a process whereby thermal energy is transferred from the hot object to the cooler object until they both acquire the same temperature), the particles lose energy and start to slow down. Now, the reverse process happens leading to fewer collisions and less pressure (some of the gas particles even condense to a liquid form and pack closer together). The pressure reduces to a value less than the atmospheric pressure; therefore, the balloon is sucked into the flask.
By the end of this experiment, students should have learnt that:

- Substances expand and exert pressure on their surroundings when heated.
- Particles slow down when cooled and exert less pressure on their surroundings.
- Liquids take up much less space than gases.
- Atmospheric pressure is pushing on objects.

### 2. ***Can crush***

This experiment is a demonstration of the effect of unbalanced forces on objects. Students should understand that pressure is a force applied on a unit area.
By heating the water in the can, heat energy breaks the bonds between the water particles, transforming them into a gaseous state. Further heating transforms the thermal energy into kinetic energy of these gaseous particles which will occupy more space. Because the can opening is not closed, the gas particles can escape in the form of steam, as will be observed by the students. When the can is inverted into the cold water, the steam cools and condenses, thus it occupies less space and there are less collisions. In other words, there is less pressure inside the can. This pressure is less than the atmospheric pressure pushing on the outside of the can. Because the students are holding the can in its place, the unbalanced forces (due to differences inside and outside the can) will cause the can to crush. Normally, the effects of atmospheric pressure are not obvious because the pressure inside the can is similar to the atmospheric pressure outside the can. This is similar to our bodies where the internal pressure inside our bodies is about equal to the atmospheric pressure surrounding us.
By the end of this experiment, students should have learnt that:

- When a gas cools in a closed environment, it creates an area of reduced pressure (vacuum).
- Atmospheric pressure exerts a force on objects.
- When a closed environment has a lower pressure than the atmosphere, the force could cause the object to contract and vice versa. Higher internal pressure may cause the object to expand or even explode. This is why astronauts have to wear their spacesuits to maintain the pressure immediately outside their body at a suitable level to compensate for their internal pressure. You can read more about this topic at https://er.jsc.nasa.gov/seh/suitnasa.html

### 3. ***Fountain experiment***

Again, this experiment demonstrates the concepts of unbalanced forces. The flask was partially filled with water, and the rest of the flask contains air particles. When the water in the flask was heated to the boil, liquid water was transferred to a gas which occupies a larger volume and hence some of the gas escapes from the opening of the glass straw.

By inverting the flask in the cold water, the gas starts to condense to form liquid, which occupies less space and creates a vacuum. Now the pressure inside the flask is less than the atmospheric pressure. This pushes down on the coloured water in the beaker, causing it to draw the solution up towards the tube into the lower pressure environment.
By the end of this experiment students should have learnt that:

- Any empty open space is filled with air.
- When a gas cools in a closed environment it creates space (vacuum).
- Similar to how unbalanced forces acting on an object causes motion, if there is a difference in pressure between two areas objects will move as pressure is force per unit area.

4. ***Relation between boiling temperature and pressure***

This experiment shows the dependence of the boiling temperature on the external pressure. Boiling happens when the vapour pressure inside a liquid is equal to the atmospheric pressure. Therefore, if you boil water at the top of mount Everest where pressure is about 34kPa compared to 101.325 kPa at sea level, the boiling temperature will be $71^0$C (compared to $100^0$C at sea level).
By putting a stopper on the flask, you are separating the environment inside the flask from the external environment. The stopper was placed when the water is boiling, then by allowing the water to cool this causes water vapour to condense creating vacuum. Now, the pressure inside this isolated system (the inside of the flask) is less than the normal atmospheric pressure, therefore water starts to boil at a lower temperature.
By the end of this experiment, students should have learnt that:

- The meaning of boiling temperature.
- The dependence of boiling temperature on pressure.
- Boiling can happen by reducing the surrounding pressure.

5. ***Effect of differential pressure on motion of objects***

The concept of this experiment is similar to experiments 2 and 3. By placing the ignited paper inside the flask and placing the egg on top, air molecules inside the flask gain kinetic energy and escape from the flask. Now, the pressure inside the flask is less than the atmospheric pressure which pushes on the egg forcing it through the opening of the flask.
By the end of this experiment, students should have learnt that:

- Air occupies all open spaces.
- Thermal energy is transformed to kinetic energy.
- By creating areas of different pressure, objects can be forced to move.

6. ***Air pressure is pushing in all directions***

This experiment demonstrates two concepts, the first is similar to experiments 2, 3 and 5 while the other concept is that air pressure is pushing in all directions. The egg is being pushed inside an inverted flask when we create an area of lower pressure inside the flask.
By the end of this experiment, students should have learnt that:

- Thermal energy is transformed to kinetic energy.
- By creating areas of different pressure, objects can be forced to move.
- Atmospheric pressure is pushing from all directions.

7. ***A challenge on how to get the trapped egg out of the flask***

This experiment is an application to what the students have learnt so far, they have to think of a way to get the egg out of the flask.
The students should know that to make an object move they have to create areas of different pressures. The object will move from the area of higher pressure to that of lower pressure. By increasing the pressure inside the flask and making it higher than the atmospheric pressure, the egg will be forced to move to the outside.
A typical way is to blow inside the flask while it is tilted, you must seal your mouth to the flask to create the area of greater pressure.

**Conclusion**

Students will state whether their results agree with their hypothesis or not. They can take a video clip of their experiment to upload on the school website or on YouTube. They can also exhibit their experiment in a science fair.

**References:**


Figure 1 https://www.flickr.com/photos/nh53/5718670915/in/photolist-9HkFCp-7xLzim-skH6vR-K2C7r-8wJxFy-itQgz6-6bXDCL-nxEwT3-6FRiDs-cYUXxQ-e5fAWe-XwChFM-boJUHz-owU8hy-ds2xGy-aof8cG-8LtLA1-cYQnE9-Ae5WS5-5fvE8W-ef7pru-9Hoyos-3zdfN9-c3vNi7-amgUNq-6Cd2sQ-dotDUv-eeA5fh-SXbvzz-3H71ot-69uCmg-c1KjpL-qSEJVx-cmEAAE-K2C7i-c3v4es-nN2GgW-8a6MN9-mUMZMB-nBpmfM-Td7stj-e9q7P9-o1h2M9-XmF9ot-ceneH-VC1eor-fyEuFh-cptdRf-vTbiAL-69zmq7 Author NH53 Licence https://creativecommons.org/licenses/by/2.0/