











Colourful fish, strange species, coral landscapes, shipwrecks and even ancient cities are only 5% from the total treasures one can find in deep oceans! Build your own submarine and experiment with it to learn how the principles of buoyancy help drive these ships.

- What Archimedes Principle is.
- How submarines use buoyancy to dive deep.





build a hydraulic platform

moves by the use of hydraulic pressure from

engineering. Build an experiential platform which

pistons. Learn how pressure is transferred inside

tubes and watch it lifting heavy objects with little

Hydraulics have multiple applications in

What Pascal law states.

• How a hydraulic press works.

build the communicating vessels build a siphon device

Since ancient Rome, water was transferred throughout towns by connecting large containers of water. Build and discover how communicating vessels work and observe the level of water inside the tube!

- How communicating vessels work.
- What artesian wells are.

Have you ever wondered how you can empty the fluid from a tank when there is no hole on its bottom? The siphon device can transfer fluids from one container to another! Experiment with this model and magically swap water between the two cups.

- What a siphon device is.
- How you can create an "upward" flow.

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Product Code: **STEM45**

Science • Technology • Engineering • Mathematics

FLUID DYNAMICS

archimedes principle, buoyancy & streamlines

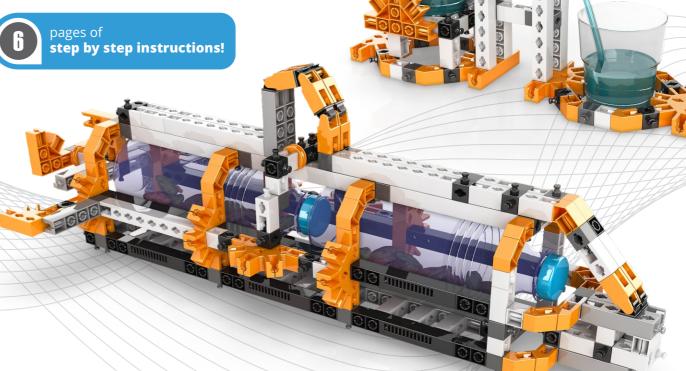
One of the most important areas in physics is the study of fluids and their fundamental principals. Water and air are the two most important elements for life and both are categorized as fluids. Air motion is what determines the temperature in our rooms. Pipelines are providing water to our homes. Industrial and construction machines use hydraulics to easily lift heavy objects. Airplanes and ships change direction by using aerodynamics and hydrodynamics respectively. Have you ever wondered why objects sink into water, while others float? How does blood flow in our body? How do water tanks operate? With this set you can build 6 different models, including a boat and a submarine, as well as various experimental rigs to learn all about fluid dynamics! Printed building instructions for 4 models are included and 2 more models are available online and through the free kidCAD app for smart devices. The printed booklet also presents the background theory and amazing facts about the subject, explaining Archimedes principle, buoyancy, hydraulics and many more! A Quiz section is also available to challenge your newly acquired knowledge.





















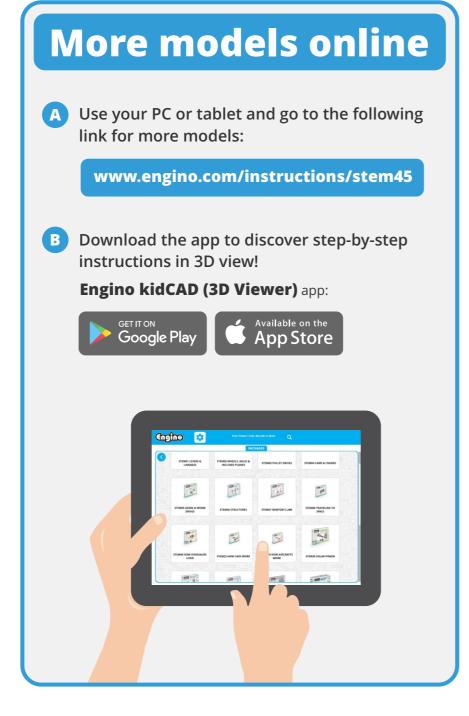




Discovering **STEM**

The purpose of STEM education - Science, Technology, Engineering and Mathematics - is to provide students with the necessary skills, knowledge and experience in order to cope with the technological challenges of the future. Modern pedagogical theories suggest that the study of engineering should be incorporated in all other subjects, starting from elementary level. DISCOVERING STEM series offers a practical solution for facing all these educational issues, aiding the teacher to engage students in STEM disciplines in a fun, exciting and interesting way! The educational packages are also ideal as a home learning tool! The series covers a broad area of subjects: Mechanics and Simple machines, Structures, Newton's Laws, Renewable Energy and even Programmable Robotics.









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STEM Science · Technology · Engineering · Mathematics

Theory

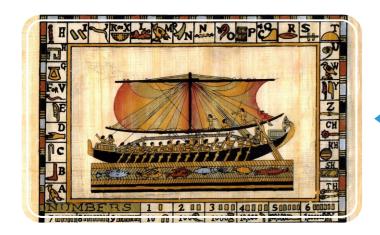
What we will learn

One of the most important areas of physics is the study of fluids and of their principles. Water and air, the most important elements for life, are both fluids. The motion of air is essentially determining the temperature in our rooms. Pipelines are providing water to our houses. Have you ever wondered why objects sink into water, while others float? How does blood flow in our body? Why are propellers used both on aeroplanes and ships? How are pipes used to empty a water tank?



Water is one of the most studied fluid

This booklet of **Discovering STEM: Fluid dynamics** contains a comprehensive **theoretical section** and interesting facts, so that you learn all about their applications in daily life. Discover all the scientific principles applied through **experimentation** and through provoking exercises. Follow the building instructions, contained in this booklet and also online, to build exciting models such as **a submarine**, **a hydraulic platform**, **a hydrostatic tower**, **communicating vessels**, **a siphon device** and **a catamaran**. Take the revision quiz to test your newly acquired knowledge.

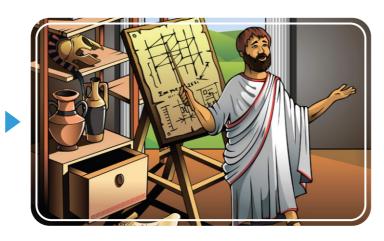


A boat on an ancient papyrus

One of the most famous scientists from antiquity is **Archimedes**. He is considered as one of the greatest mathematician, inventor and physicist of all times. Due to his cleverness, he was frequently given puzzles to solve. One day a king asked him to determine whether his crown was purely made of gold or had any other mixtures. Archimedes solved this puzzle while having a bath, and became the first man who understood the basic principles of sinking objects into fluids.

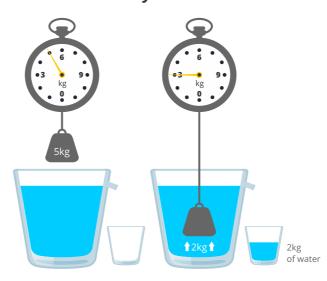
History of fluid mechanics

Ancient civilizations were established close to locations where water supplies were abundant, such as rivers and seas. Without any mathematical knowledge and using only empirical conceptions, they were able to build structures to protect them from river overflows. They also developed simple rafts to cross the seas and exchange goods with neighbours.



Archimedes (287 - 212 BC)

During his bath, Archimedes noticed that the level of water in his bathtub was raising while he was sinking into it. Indeed, the more of his body was sunk into water, the higher the level would rise. This crucial observation made him think on ways to corelate the volume of his sank body to the level of raised water. He came to the conclusion that the volume of the displaced water, is equal to the volume of body which is sunk into it.



Did you know?

Archimedes was a great inventor. A machine which is still used today is called "Archimedes screw". it consisted of a large circular pipe enclosing a helix, with its lower end dipped in the water. The rotation of the device was causing the water to rise in the pipe and ultimately collect it on the top. It actually worked as a primitive well.



Archimedes screw used for raising water



Water level raises while an object sinks into it.

Archimedes Principle

With further experimentation, Archimedes realised that objects weigh less when sunk into water! He understood that there must be a force that works in opposition to weight. In one of his books, Archimedes stated that "any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object." This is known as the Archimedes Principle. This is a fundamental principle of physics which explains why some objects can float,

To solve the puzzle of the crown, Archimedes borrowed pure gold, of the same weight, from a different goldsmith. The two had the same weight when measured outside of water. However, if they had different densities, hence different volumes, they would displace different quantities of water. Thus, the two bodies would weigh different into water! Indeed, the crown proved to be impure, as it weighted less than pure gold!





instead of sinking!

Submarine:

Observe the archimedes principle and understand buoyancy phenomenon.



Engino[®] "Submarine" model

Fluid Mechanics

We are all familiar with the 3 states of matter, which are solids, liquids and gases. A common characteristic between liquids and gases is the fact that they can flow and change shape according to the volume in which they are placed. The ability of a material to flow is essentially the reason to be called as **a fluid**. The brunch of physics which studies the behaviour of fluids is called fluid mechanics. When studying a fluid in motion, the field is called **fluid dynamics**.



Oceans, air and clouds are fluids

Underneath the surface of our planet lies a very hot fluid, called **lava**. This glowing hot fluid is essentially rock, which has melted due to the high pressures and temperatures that occur in the interior of Earth. Geologists need to apply the laws of fluid dynamics to predict and understand the process of a volcanic eruption.



Galaxies and stars are also fluids



Gases and liquids are considered as fluids

Fluids in nature

To appreciate the field of fluid dynamics we only have to look around us. Consider that nearly 70% of the Earth is covered by water, while all of its atmosphere is gaseous. Ocean circulation patterns and weather forecast is achieved due to the understanding of how fluids move. From a biological viewpoint, our bodies are mostly made of fluids and all cellular activities involve fluids.



Volcanic lava is also a fluid

Let us leave the Earth and ponder at our vast Universe. A spiral galaxy is mostly made of hydrogen gases. To understand the motion of a spiral arm, astrophysicists have to apply laws of fluid dynamics. In addition, stars are made of extremely hot gases. The physical processes that undergo both in the interior and on the surface of stars, are understood by applying the principles of fluid mechanics.

Forces and Pressure

Force

We cannot see forces, but we can understand their effects when they are applied on an object. When a force is applied, it has the ability to make the object move or change its shape. We have to push a huge box to make it move. When we pull a rubber band we can see that it stretches. A can is squeezed by the force applied from our hand.



A balloon suffers more pressure when is pushed with a pin rather than a finger

Did you know?

Scissors are a great example of how pressure depends on the surface. The two blades are sharp in order to assure that high pressure will be exerted on small area to cut the sheet with little effort. The reason of dropping performance after long time of usage, is that blades lose their sharpness and get thicker.



Scissors cut paper by exerting large pressure on small area



In order to move an object or change its shape a force must be applied

Pressure

From our daily experience we know that if we push a balloon with our finger, the balloon will only deform. However, it takes little effort to tear a balloon when we push it with a pin. This is because the force is concentrated into the tiny area at the point of the pin. Thus, the amount of force acting on an area is called **pressure**. When the same force is applied on a smaller area the pressure is higher!

Hydrostatic Pressure

Fluids can exert pressure just because the piled-up layers are pushing the layers beneath them. These forces are developed inside a fluid due to its own weight and create pressure. Therefore, the amount of pressure that fluids can exert due to their weight is called **hydrostatic pressure**. The hydrostatic pressure depends on the depth, since deeper layers feel more weight. Also, denser fluids produce stronger pressure as more mass in condensed into the same volume.



- **P** = Pressure
- ρ = density of fluid
- **g** = gravitational acceleration
- **h** = depth

Buoyant Force

Archimedes discovered the buoyant force and explained how to quantify it. That was very helpful for ship designers as they could predict whether the designed vessel would properly float. However, Archimedes could not truly explain how this force was generated. Buoyancy can be explained by understanding hydrostatic pressure.

In fact, buoyancy is generated due to the difference of hydrostatic pressure between 2 points. When an object is partially immersed into a fluid, its bottom area is subjected to hydrostatic pressure. Thus it feels an upwards push. When it is immersed deeper, the pressure is higher and buoyancy is larger.

$F = \rho \times g \times V$

F = Buoyant force

ρ = Density of fluid

g = Gravitational acceleration

V = Volume of discalced fluid

Formula for buoyant force



An ocean liner floats over water

The formula above gives the buoyant force which an object feels when immersed into a fluid. The value of this force is determining whether the object will float or sink. If the force of buoyancy is larger than the weight of the object, then the object will **float!** Contrary, if the buoyancy is smaller than the weight of the object, it will sink! Thus, the displaced volume is key for marine engineering.

•2

Hydrostatic pressure differs by depth

Did you know?

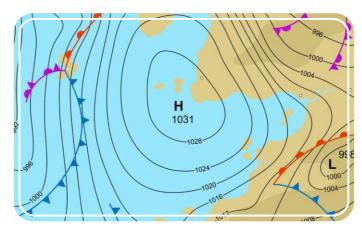
Scuba divers are well aware of the hydrostatic pressure and the dangers they are exposed to, because of higher pressure in deep waters. As a diver descends, pressure causes spaces of air in their bodies to compress. Delicate membranes, like the ear drum, can get sucked into theses air spaces, causing pain or even injury. To overcome this, divers have to do ear equalization, an exercise that balances air pressure among the two sides of the ear drum.



Divers have to be careful in deep water

Atmospheric pressure

The Earth is surrounded by a gaseous layer, called the **atmosphere**. It is actually the air we breathe, mostly made of nitrogen, oxygen and few traces of carbon dioxide. The atmosphere extends up to 100 kilometres above the Earth's surface and its density drops when going to higher altitudes. This is why breathing assistance is demanded when climbing high mountains, such as the Everest or Mont Blanc. The thin atmosphere provides less oxygen to our lungs.



Pressure maps help meteorologists

Building Challenge

Hydrostatic Power:.

Experiment with this model to learn how *hydrostatic pressure* differs by depth. Let the water pour from different heights and observe the power of the stream.





Engino[®] "Hydrostatic Power" model



The Earth's atmosphere

Just like fluids, air can exert pressure because of its weight. The air pressure is called atmospheric pressure. On the bottom of the atmosphere, which is the Earth's surface, maximum pressure can be observed. The pressure variations that occur, either by altitude or due to temperature differences, are determining the weather conditions.

Torricelli's law

A very simple experiment to demonstrate the increase of hydrostatic pressure by depth was done by the Italian physicist **Evangelista** Torricelli. He made three holes on a tube and filled it with water. The water was pouring outwards from the holes, but not with same power. The lower hole was ejecting water with more power, whereas the upper stream was very weak. This happens just because hydrostatic pressure is stronger deeper inside the tube. Torricelli managed to find the mathematical formula to relate the speed of the jet with the depth of the hole.



The water jet is more powerful when it pours from lower position

Pascal's Law

One of the most important contributions in the field of fluid mechanics was done by **Blaise Pascal**, a French physicist and mathematician. Just at the age of 16, Pascal showed his outstanding abilities in mathematics by deriving his very first theorem. His interest in physics was mostly focused on fluids and pressure. His findings set the foundations of fluid dynamics. Pascal was experimenting on measuring the precise value of atmospheric pressure.

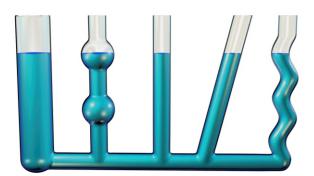


Blaise Pascal (1623 - 1662)

In fact, he was the first who demonstrated that it can vary from place to place and explained the variation due to altitude difference. The fundamental principle, called as **Pascal's law** states that "when a pressure change occurs in one part of a fluid, it is transmitted without loss to every portion of the fluid and to the walls of the container".

Communicating Vessels

A straightforward application of Pascal's law are the **communicating vessels**. When two or more containers are connected with a pipe, then any fluid poured inside will settle at the same level in each jar. If more fluid is inserted inside one of the vessel, the whole system will readjust in order to keep the fluid levels equal. This property does not depend on the shape of the vessels, nor on the volume they have.



The fluid level is equal despite the vessel's shape

The explanation comes by understanding the Pascal's law. Atmospheric pressure is pushing the fluid downwards while the fluid has to fill into the system of vessels. Since the atmospheric pressure is equal horizontally, then the fluid will occupy such volume in order to keep its levels equal.



The barometer is an instrument that measures air pressure. It was invented in 1644 by the Italian scientist Evangelista Torricelli, a student of Galileo Galilei. When air pressure is low, it is a signal for rainy and stormy conditions. Dry and fair weather conditions can be predicted when atmospheric pressure is high. By monitoring the changes of atmospheric pressure, meteorologists can predict the weather conditions above a region.



A barometer measures atmospheric pressure



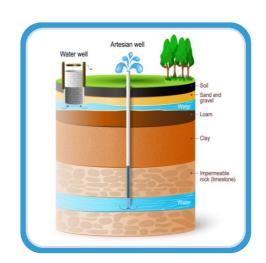
instructions can be found online

Communicating Vessels: .

Experiment with the two vessels and observe whether the level of water changes. Such constructions were made in ancient Rome to distribute water among buildings.

Artesian Wells

Out of the total water quantities on Earth, 97% is salty water while only 3% is drinking water. In addition, the majority of fresh water lies beneath its surface, in soil pore spaces and in the fractures of rock formations. These quantities of water are called **groundwater**. More than half of the US population is supplied from groundwater. It is also a major source of industrial and agricultural uses. Out of all the fresh water on Earth, only 0.36% is readily available to use.



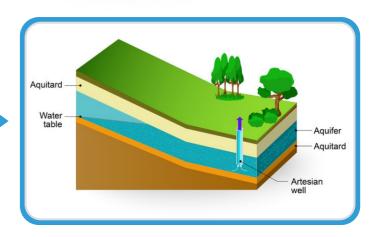
An artesian well does not need a pump

Water Tanks

Even prior to Pascal time, many civilizations used systems of communicating vessels to achieve water supply. A large and tall water tank was placed higher than the surrounding buildings, and the whole village was connected through pipelines. Water could reach anywhere without the need of a pump, since pipes were at lower level than the tank.



Engino[®] "Communicating Vesel" model



Large amounts of water lay below the ground

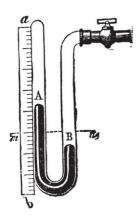
Groundwater comes from high mountains and reaches valleys through aquifers. If a well is drilled down into the aquifer, then it will act as a communicating vessel and water will come up to the ground without the need of a pump. The hydrostatic pressure is high at the bottom of the well and pushes water upwards to the ground.



A water tank placed at a tall tower

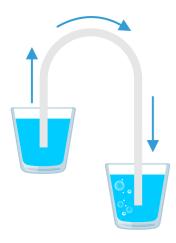
Manometers

The instruments which are used to measure fluid pressure are called **manometers**. Measuring the pressure of a fluid is essential to understand the blood pressure flowing in our body. Pressure is formally measured in **Pascal** units, honouring the great scientist. Though, other units such as bar, atm, and torr are used according to the specific application. For example, blood pressure is measured in torr units, shortened name of Torrichelli.



A "U" shaped manometer

When only atmospheric pressure acts on the tube sides, the fluid level will be equal at both sides. However, when additional pressure is exerted from one side, the fluid column within the glass tube will move towards the other side. The raise of the fluid level is proportional to the additional pressure. For example, we can pour oil in one side and measure the change of the height of the other side. Thus we can measure the hydrostatic pressure of oil column.



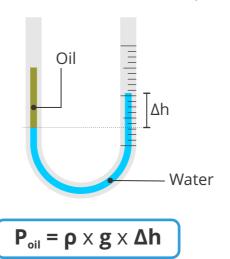
The siphon mechanism is used to empty a container



Manometers measure blood pressure

U-shaped manometers

Pascal's law can be applied on a U-shaped glass tube which is filled with a liquid. This is a very simple and reliable method to measure pressure. The levels of the fluid should be equal, as far as no external force is applied. When pressure is exerted in one side, the fluid column moves and raises on the other. The side is scaled in order to measure. Hence, by only measuring the change in fluid level we can find out the pressure.



Siphons

The **siphon mechanism** is used to empty a reservoir through a pipeline which is placed above the fluid level. It is actually an inverted 'U' shape that causes a liquid to flow upward with no pump. This can be achieved by evacuating the atmospheric pressure from the tube, in order to initialize a flow under the pull of gravity. Thus, we can transfer a fluid at a lower level.

Hydraulic machines

A major application of Pascal's law are the mechanical properties of fluids when compressed by pistons. This branch of physics is called **hydraulics** and has multiple applications in engineering. Examples of machines which use such systems are car breaks, construction vehicles, forklifts and industrial arms.



Hydraulics make tyre change easier

Did you know?

When we watch an iceberg floating in ocean, we actually see only 10% of its natural size. The rest lies below the sea surface! This happens due to water's strange behaviour when freezing. While the majority of liquids lessen their volume as they freeze, water expands. Therefore, ice has 10% lower density compared to liquid water.



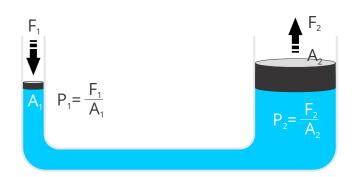
An iceberg is hidden below the sea



A construction machinery lifts heavy loads due to hydraulic pressure pipes system.

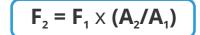
Hydraulic press

A very important advantage of hydraulic machines is that they provide an efficient method of multiplying forces. Small forces can be amplified and used to move heavy objects. A basic design of such a device, called **hydraulic press**, is constituted of a tube that has two apertures of different diameters and a fluid filled inside.



A typical hydraulic press

Due to **Pascal's law** the pressure should be equal at both sides. Thus when a force pushes the piston on one side, the same pressure will be transferred to the other one. The difference in the area between the two sides is working as a force magnification!



 \mathbf{F}_1 = Income force

F₂ = Outcome force

 A_1 = Area of small piston

 A_2 = Area of large piston

Formula for hydraulic press

Bernoulli's principle

Daniel Bernoulli, an eighteenth-century Swiss scientist, discovered the principle which relates the speed and the pressure of a flowing fluid. He noticed that the pressure was lower when the fluid was flowing into a narrower part of the tube. He stated that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure. The high pressure region is pushing towards the low pressure region.



The eye of a cyclone is a low pressure region

Wings

Airplane wings are designed to make the air curl and move faster over their curved upper surface. Applying the Bernoulli principle, a fast moving air will create a low pressure region on top of the wing. Thus, the pressure difference between upper and lower region of the wind will create a net force. This force, called **lift**, pushes the wing upwards and thus the aeroplane into air.



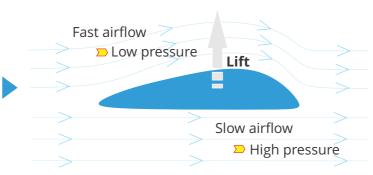
Propeller is used to increase the airflow

Slow Fast Slow

In the narrow region of a tube, the fluid moves faster while its pressure drops

Fluids in motion

We know that wind is nothing else but air in motion, while waves are moving water. The study of moving air is called **aerodynamics**, while for water it is called **hydrodynamics**. Meteorologists can predict the trajectory of a hurricane when approaching a coast and at what speed it will pass over a city. The eye of a cyclone is a low pressure region, thus strong inward winds are formed in spirals around it.



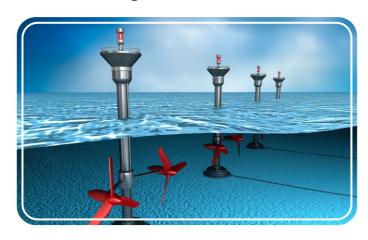
Airflow lines around a wing

Propeller

A propeller is essentially a spinning wing which produces a forward lift, called as **thrust**. The air pressure difference between the front and back surfaces of its blades is achieved through its rotary motion. In order for a propeller blade to spin, it usually needs the help of an engine. A ship's propellers create thrust in water in much the same way as airplane's propellers create thrust in air.

Applications of fluid dynamics Aviation

Aerospace engineers have to understand all the phenomena that occur while a rocket is flying to space, in order to design stable and reliable flights. These include how air flows around, the necessary power for take off and the selection of proper materials for robust and effective flight of the rocket.



Propellers use tides to generate electricity

Did you know?

Natural gas is odourless and energy companies add the smell of rotten egg in order to enable customers to detect natural gas. The artificial smell of natural gas is also helpful in cases of gas leaks, since gas can be detected by the strange smell. Only in the US, there are over 300,000 miles of interstate natural gas pipelines, more than enough to reach the Moon!



Pipelines with a pressure gauge



Rockets are powered by liquids and gases

Green Energy

Wind turbines and solar panels are the most known mechanisms that produce electricity from renewable sources. A new form of green energy though, called **tidal power**, converts the energy of tides to electricity. Tides are far more predictable compared to winds and sunshine, however engineers have to overcome the difficulties of low water flow and limited availability of sites.

Gas Network

Natural gas comes out of the ground under pressure, so the most effective way to transport is using a series of compressor stations. Highly complicated and sophisticated **pipelines** are necessary to connect the stations and safely transfer the gas. Powerful compressors, similar to jet engines, move natural gas through the pipeline network at around 40 km an hour.



Natural gas station

Learning about: Fluid Dynamics

Hydrostatic Tower

There is a specific depth limit that a diver can reach underwater. If this limit is exceeded, divers may suffer from eardrum injuries. Experiment with this model to find out how pressure changes by depth.

Discover:

- What is hydrostatic pressure?
- Which factors affect hydrostatic pressure?

Level of Difficulty ★★★★

Learning about: Fluid Dynamics

Communicating Vessels

It is interesting that kettles use simple physics to indicate the amount of liquid which is left into the pod. Build your communicating vessels model to find out how kettles use this principle.

Discover:

- What are communicating vessels?
- How do communicating vessels work?

Level of Difficulty $\star \star \star \star \star$

Materials Needed:

- Engino[®] Fluid Dynamics (STEM45).
- A plastic cup (see page 23).
- Water.

Procedure:

- 1. Find the instructions online and build the Hydrostatic Tower model.
- 2. Push the piston all the way inwards in the **syringe** and join the syringe with one nozzle of the rubber tubing. Take a plastic cup and fill it with water. Place the other side of the rubber tubing into the cup. Then, pull the piston outwards to fill the syringe with water. Attach the syringe on top of the model, as shown in below image. Place the nozzle of the rubber tubing on **position A** and do exercise 1.



- **3.** Place your model in front of a sink, with the nozzle facing the sink. Now, remove the piston, observe what happens and do exercise 2.
- **4.** For **case 1** place the rubber tubing on position A. For each case the nozzle of the rubber tubing should be on the edge of the hole. Fill the plastic cup with water and pour it into the syringe. Observe the intensity of the flowing water. For cases 2 and 3 place the nozzle at **positions B** and **C**, respectively. Repeat the same procedure and write your observations in the table of **exercise 3.** Then do exercise 4.

1. Does the water pour out from the rubber tubing? Why is this happening?

2. Fill the gaps of the following paragraph by using the words from the box.

> atmospheric pressure, pour, air, not poured,

When the syringe is sealed by the piston, the water is But, by the time the piston is removed, pushes the water and makes it outwards. Water is forced to eject due to existence of

3. Complete the table according to your measurements. Use the words: weak, moderate or **strong** to describe the intensity of water.

Case	Position	Water intensity
1	А	
2	В	
3	С	

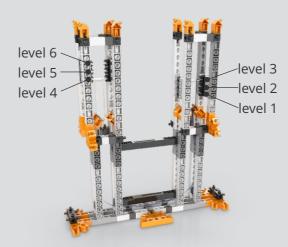
4. Which factor affects the intensity of	Deawayh
ejecting water? Use hydrostatic	P = ρ x g x h
pressure formula to explain your answe	r.

Materials Needed:

- Engino[®] Fluid Dynamics (STEM45).
- 15 ml of water.

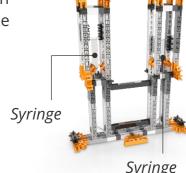
Procedure:

- 1. Find the instructions online and build the Communicating Vessels model.
- 2. Remove the pistons from the syringes and complete exercise 1.
- 3. For case 1 place one syringe on the 4th level and the other one on the 3rd level as it is shown below. Add half teaspoon (2.5 ml) of water into one **syringe**. Let the water settle and observe the water level into the two syringes.



- **4.** For **case 2** change the positions of the **first** syringe to level 5 and of the other one to **level 2**. Levels are shown on the picture above. Observe the water level for this case.
- **5.** Then, for **case 3** switch the position of the first syringe on level 6 and of the other one on level 1. Recall your observations for all three cases and answer exercises 2 and 3.
- 6. Add another half teaspoon (2.5ml) of water into the **first syringe**. Observe again the level of water and answer exercises 4 and 5.

1. Join the two syringes with the rubber tubing and place them to the appropriate positions as shown on the image beside.



2. Do you observe something interesting about the level of water for all three cases? What is this?

3. Fill in the gaps below using the words from the box to write your conclusion.

> always, atmospheric pressure, communicating vessels, level

The two syringes work as
syringes is at the same
This is because the
is equal in both
sides.
4. What changes do you see when adding more
water?
5. Will the level of water change if you use vessels of

different shapes or sizes?

Learning about: Fluid Dynamics

Siphon device

Siphons are used to empty liquids from tanks, that would otherwise be impossible or difficult to do. A fish tank is a great example of how siphon devices are used to refresh water.

Discover:

- What is a siphon device?
- How does the siphon device work?

Level of Difficulty ★★★★

Learning about: Fluid Dynamics

Hydraulic Platform

Materials Needed:

How is it possible to lift up a car to change a flat tire? A hydraulic system is used to make this possible! Build this fascinating model to understand how you can lift heavy objects with little effort.

Discover:

piston of the large syringe?

- What does Pascal's law state?
- How can you easily lift up heavy objects?

Level of Difficulty	1 7	7	イプ	7 *	

Materials Needed:

- Engino[®] Fluid Dynamics (STEM45).
- 2 Plastic cups (see page 23).
- Water.

Procedure:

- **1.** Find the instructions in **pages 23-28** and build the Siphon Device model.
- **2.** Fill a plastic cup with water, until half full. You may use food colouring to observe better the water flow.
- 3. Place the plastic cup with water on base A and the empty one on **base B**. Place the nozzles of the rubber tubing into the plastic cups and do **exercise 1**.
- **4.** Take the **syringe** and push its piston all the way inwards. Take the nozzle of the rubber tubing from the empty cup and join it with the syringe. Pull the piston outwards until the rubber tubing is fully filled with water. Make sure that **no air bubbles** are left into the tubing!



- **5. Carefully** detach the syringe from the rubber tubing and quickly place the nozzle into the cup. Observe what is happening and notice the flowing direction of water. Then, answer exercises 2 and 3.
- **6.** Empty both cups and fully fill cup A. Place the empty cup at base B. Repeat the experiment, as described in steps 4 and 5. Answer the questions of exercises 4 and 5

1.	Is the	water	poured	into	the e	empty	cup? (Can y	ou/
th	ink of	why is	this ha	ppen	ing?				

2. Fill the gaps of the following paragraph by using the words from the box.

flow, atmospheric pressure, air

While we fill the rubber tubing with water we also remove Thus, there is no into the tubing. When the syringe is detached and the nozzle is placed into the cup the water starts to **3.** When does water flow stop? How much water is left in cup A?

- **4.** How much water is left in cup A in this particular case?
- 5. When does water flow stop? Look at the water level on both cups. Do you notice any interesting facts?

Procedure:

- Pebbles.

1. Find the instructions online and build the Hydraulic Platform model.

- Engino[®] Fluid Dynamics (STEM45).

- A plastic cup (see page 23).

- **2.** Push the pistons of both syringes all the way inwards. Set the piston of the **first syringe** so that it indicates 5 ml on the readings of the syringe. Join one nozzle of the rubber tubing with the syringe.
- **3.** Join the **other syringe** with the other nozzle of the rubber tubing. Push the piston of the **first syringe** inwards and do exercise 1.
- **4.** Remove the tubing from the first syringe. Detatch the other syringe from your model and remove the tubing completely. Join one nozzle of the tubing to the **first syringe** and place it on the top of the model. It may need some push to fit properly.
- **5.** Set the piston of the **other syringe** so that it indicates 2.5 ml. Join the other nozzle of the rubber tubing with the **syringe**. Now, press the piston of it and do exercise 2.
- **6.** Fill the cup with small pebbles and place it onto the platform. Then repeat the **comparison** between pushing the two pistons by switching the two syringes as explained above. Answer the questions of exercises 3, 4 and 5.

2. Did you notice any difference in this case? Was it easier or more difficult to lift the platform?
3. When having a cup full of pebbles on top of the platform, was it easier to lift the weight when pushing the large piston or the small one?
4. Think about the Pascal' s law and look at the formula shown below. How can you explain your

answers in previous exercises?

|--|

F₂: the acting force A₁: area that weight acts onto A₂: area of exerted force

F₁: the total weight

5. Fill the gaps of the following paragraph by using the words from the box.

hydraulic, area, amplify, smaller

A machine is used to transmit pressure among its two sides. If the of the acting force is than the other, then it can a force.

1. What happens to the platform when you push the

Learning about: Fluid Dynamics

Submarine

The first submarine was built in 1860 and could dive only 4 metres deep. Today, the advancements in technology enable submarines to dive up to 500 metres. Learn how they can dive into deep waters!

Discover:

- Why does buoyancy make a ship float?
- How do submarines change their buoyant force and immerse?

Level of Difficulty ★ ★ ★ ★ ★

Materials Needed:

- Engino[®] Fluid Dynamics (STEM45).
- 2 Plastic bottles (see page 23) & some pebbles.
- Large sink filled with water

Procedure:

- 1. Find the instructions online and build the Submarine model.
- **2.** To perform this activity it is essential to have a large sink filled with water. Make sure that the sink is large enough so that the model fits into it. Also, it is important that it has a depth larger than 50 cm.
- 3. Remember that bottles have to be closed for all cases. For the first experiment leave the model on the water surface and let it free. Observe whether it floats or not and answer the question of exercise 1.
- **4.** Take your model out of the sink and remove the two bottles. The image below shows an easy way to achieve this.



- 5. Fill the two bottles with pebbles up to a quarter. It is important that you do not add more pebbles than suggested. Check the image on the right which shows the suggested amount.
- 6. Place the bottles back into the model and let it on water again. Answer the questions of exercises 2 and 3.
- **7.** For the last experiment, keep the pebbles which are inside the two bottles and fill the rest with water. Place them back to the model and check whether it sinks or floats. Answer the question of exercise 4.

2. When pebbles are added into the two bottles, does the submarine float?	

1. Does the submarine float or sink? Is the buoyant

force larger or weaker than the model's weight?

3. There are 4 different materials which are involved into this experiment. Can you name them? Can you also place them in order according to their density?

	Name of Material	High Density
1		
2		
3		
4		Low Density

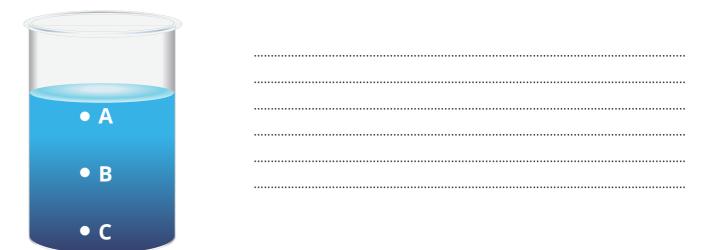
4. Does the model float or sink? Can you think of how submarines manage to dive into water when they are in mission and how they can raise back and float on the surface?

• • • • • • • • • • • • • • • • • • • •	 	



Exercise 1

Which one of the 3 points has the more hydrostatic pressure? Explain your answer. (points 2)



Exercise 2

.....

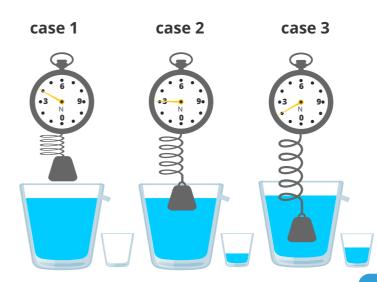
.....

a) Measure the difference of water height among points A and B. b) Calcu It is give density

late the hydrostatic pressure of the oil exerted at position C. en that the gravitational acceleration is $g=10m/s^2$ and the oil is $\rho=900kg/m^3$. (points 3)	Oil = 0.15m = 0.10m = 0.05m
	Water

Exercise 3 (points 5)

An object is weighed on a scale for three different cases. 1) Outside of water, 2) half immersed and 3) fully immersed.



a) For all 3 cases, fill the following table with the weight of the object (as indicated on the scale) and the weight of displaced water.

	Weight of object (Scale indication)	Weight of displaced water
CASE 1		
CASE 2		
CASE 3		

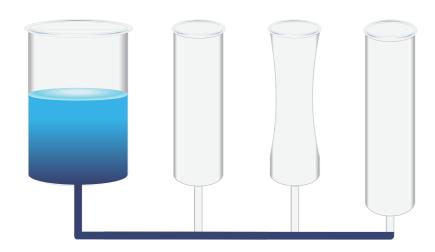
c) How much is the buoyant force for cases 2 and 3?

Case 2=N

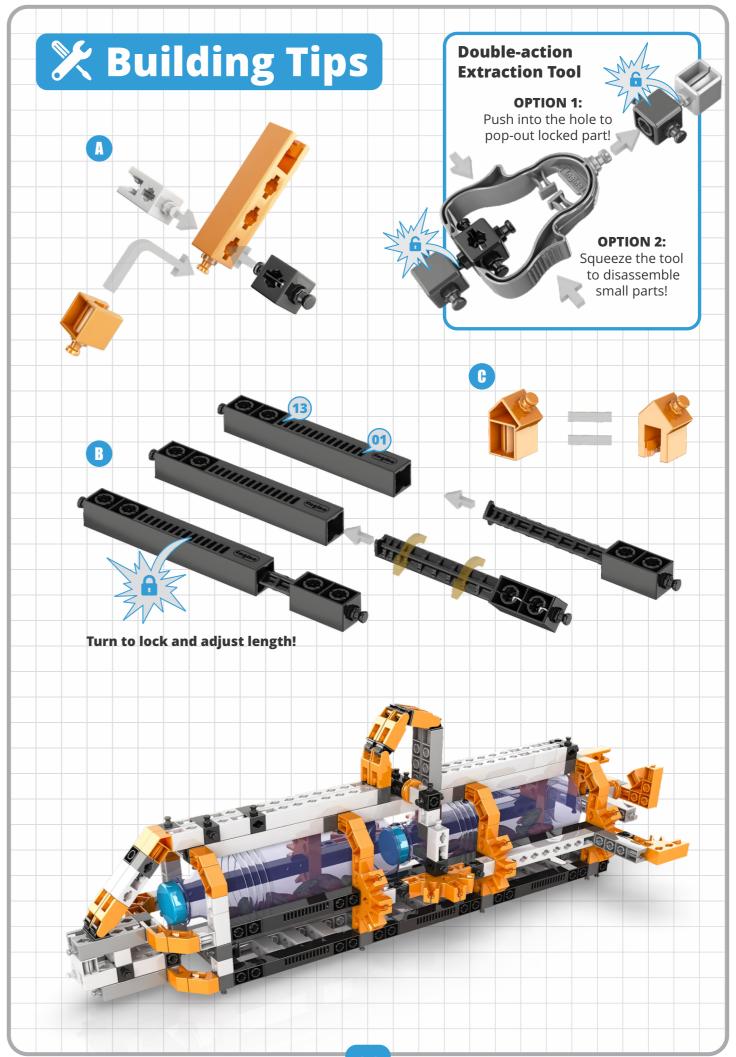
Case 3=N

Exercise 4

a) Use your pencil to colour the level of the water in each of the three vessels. (points 2)



b) How are these vessels called? How do they work? (points 2)
Exercise 5
a) A force of 500N is applied on the small piston (left one) which has an area of 0.2m². Calculate the upwards force which is acted from the big piston, if it has an area of 5m². (points 4)
F ₁ A ₁ A ₂
a) Would such a configuration be able to lift up a car that weighs 10,000N and is placed on the big piston? Explain the reasons of your answer (points 2)



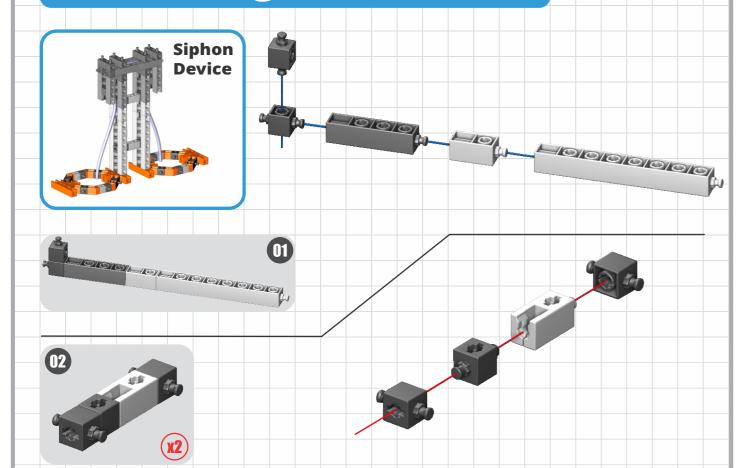
2

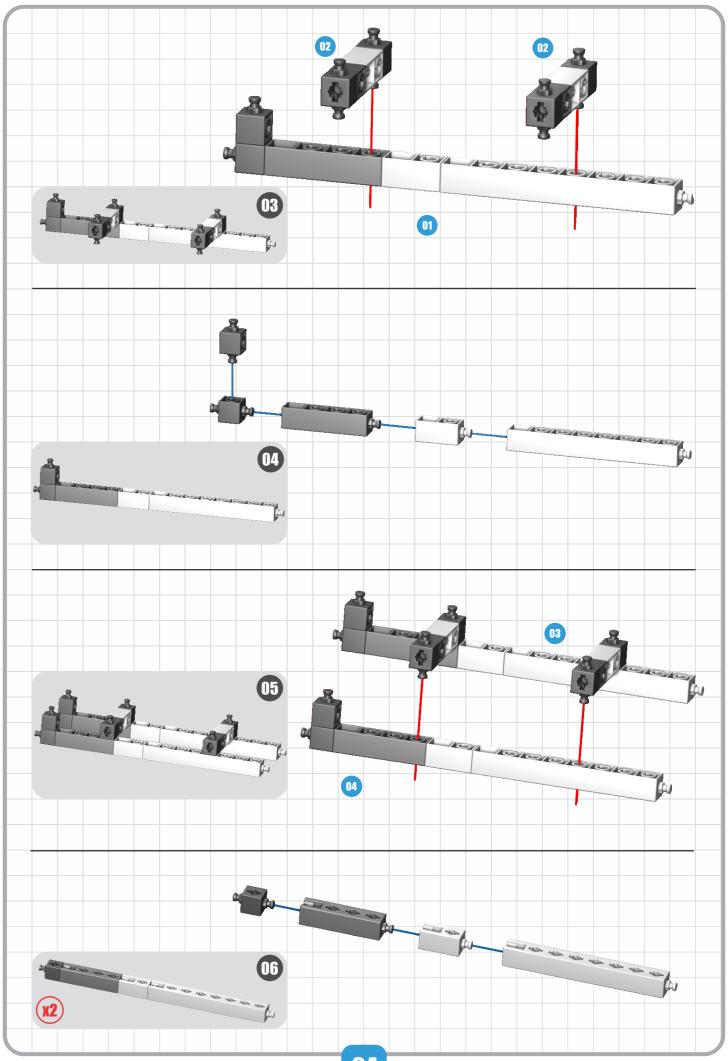
Additional Materials

To perform experiments with your models, you need two plastic bottles and two plastic cups. These materials are **not included**, but can easily be found at home or on the market. Look for the suggested dimensions in order to properly execute the experiments.

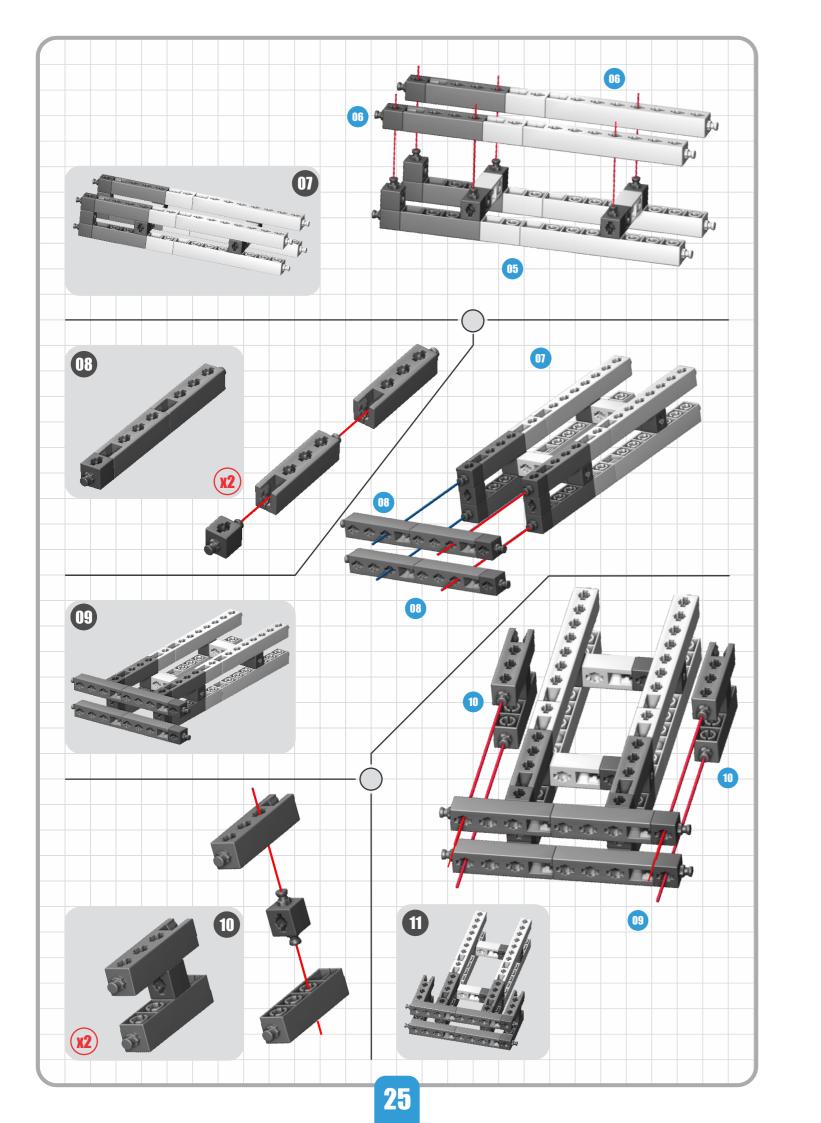


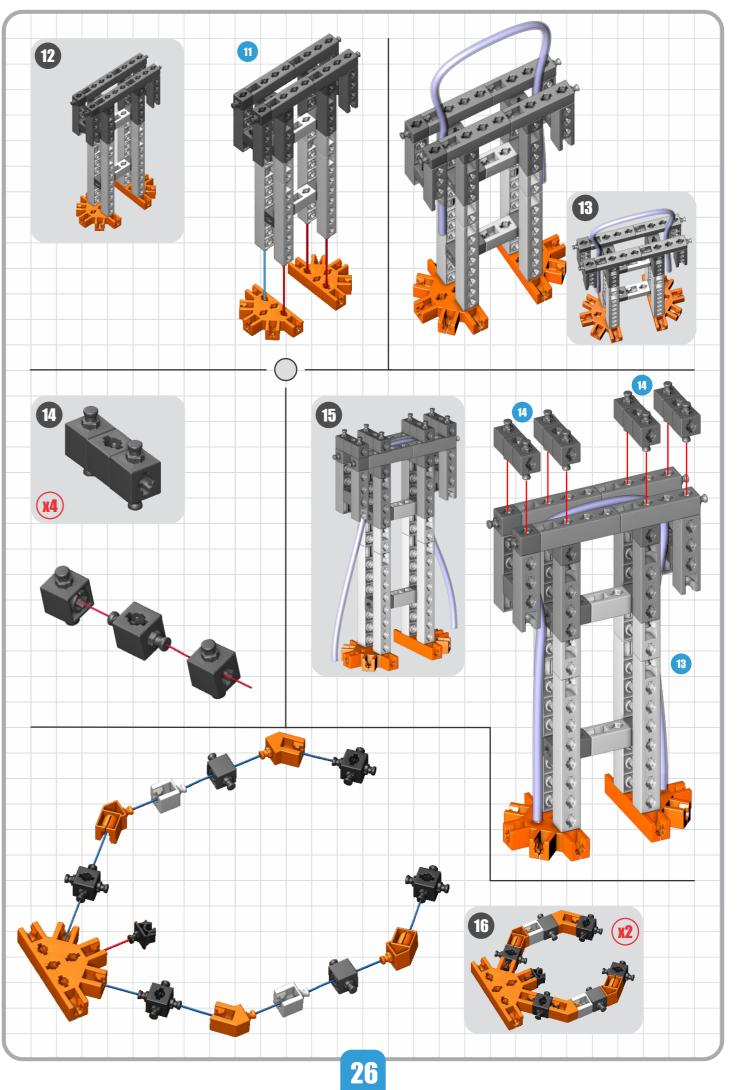
X Building Instructions

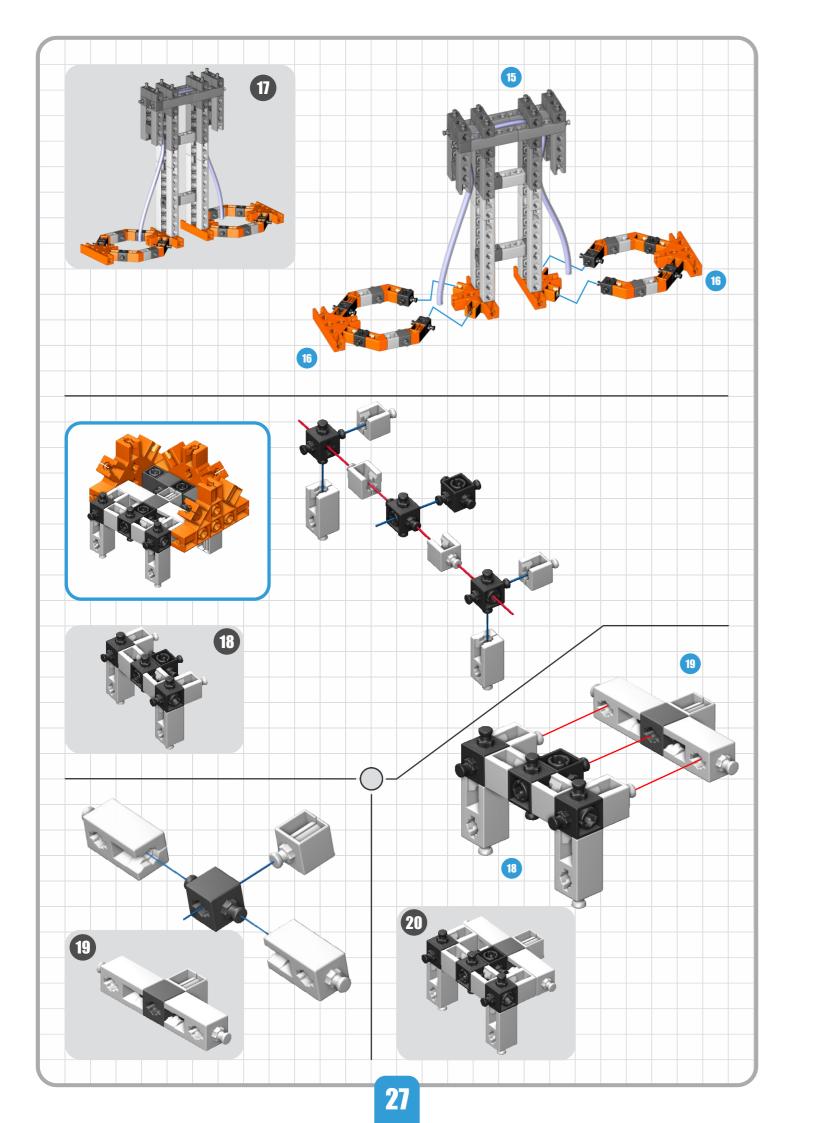


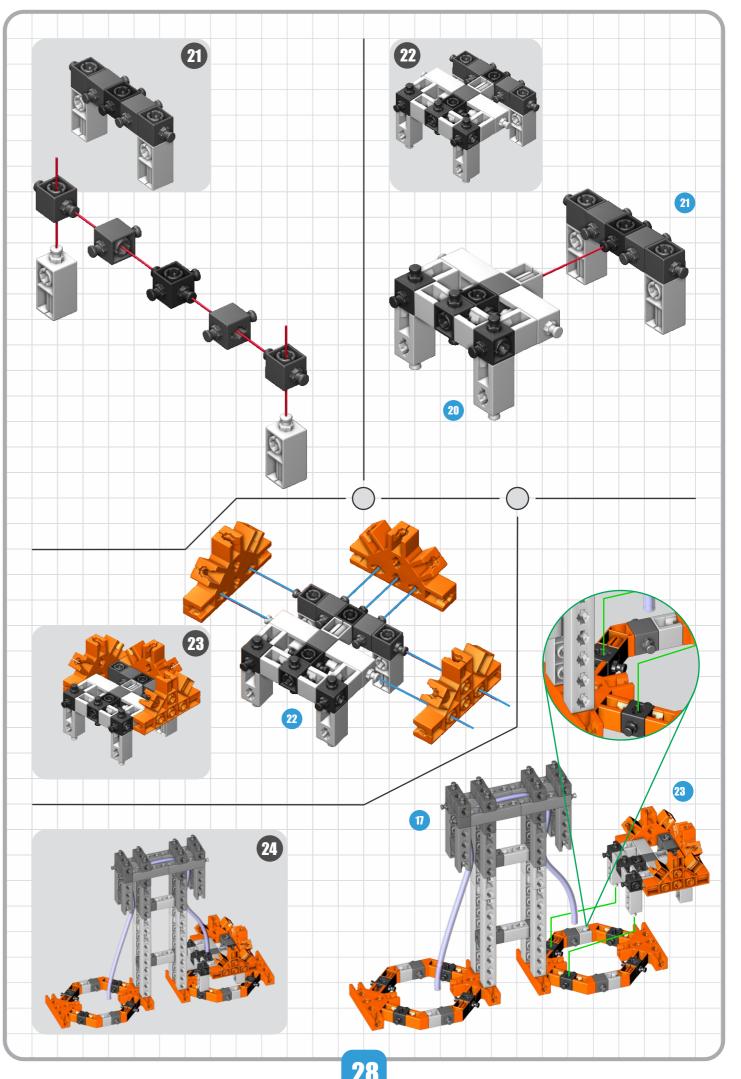


 $\mathbf{23}$









Bill of Materials



*Caution: This set contains a rubber tubing longer than 30cm (12 inches). Keep away from children under the age of 36 months. Danger of strangulation.

Warning: Experiments use water. Perform the experiments away from all electrical devices to reduce the risk of electric shock.













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