

Peter Gebhardt-Seele

Physics

Liquids and Gases Pressure/Volume/ Temperature

Experiments for the
Montessori Classroom

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TOPIC : LIQUIDS/GASES: PRESSURE/VOLUME/TEMPERATURE
MATERIALS LIST

To be ordered from

Science Kit & Boreal Laboratories
 777 East Park Drive
 Tonawanda, NY 14150-6784
 Tel: 1-800-828-7777 or
 1-716-874-6020

Please order by phone to make sure, the materials are shipped immediately,

Materials to be ordered (Catal.# = the catalog number in the "Science Kit & Boreal Laboratories" catalog)

Qty	Description	Catal.#	Price \$	Foot- note
1	Boyle's law apparatus	64710-00	12.95	
1	replacement cap	64710-01	3.65	
1	replacement syringe	64710-02	6.50	
1	Charles' law tube	61052	21.95	
1	equilibrium tubes	61609	39.95	
1	Pascal's demonstrator	45517	24.95	
1	open manometer	68949	75.-	
1	set rubber Magdeburg hemispheres (2)	62279	13.50	
1	fire syringe	64755	23.25	
1	graduated pitcher 500 ml,	64343-05	9.50	
1	graduated pitcher 1000 ml	64343-10	9.95	
1	volumetric flask, 500 ml	61755-15	11.07	
1	rubber stopper, 2 holes (Twistit stopper assortment black)	45117-00	15.95	
1	L-shaped connecting tube, o.d. 4 mm	45227-00	1.35	
1	L-shaped connecting tube, o.d. 6 mm	45227-01	1.40	
1	thermometer, red alcohol, -20 °C – 110 °C	63320-00	4.75	
3'	plastic tubing, i.d. 1/8" x 1/16" (3 feet)	62900-01F	2.25	
1	extension condenser clamp 50 mm Jaw opening	61110-02	ca. 14.90	
1	hot plate, single burner, 700 W	62070-00	35.95	

PETER GEBHARDT-SEELE

**LIQUIDS/GASES: PRESSURE/VOLUME/TEMPERATURE
MATERIALS LIST**

2/06

Several science supply houses offer kits which cover the topics Liquids and Gases. But I recommend the following collection, it is better suited to the approach used in my set of command cards.

While several suppliers have similar items in their catalogues, only for one of them the catalogue numbers are included in the following list. Order by phone, in case an item is no more available or is listed under a different number.

Horizontal lines separate sets which are packed together in the containers listed.

Qty	Description	Catal.#	Source	Price \$, '95	Foot- note
1	set of 9 <u>hooked</u> weights 10g – 1000g	60465-00	1	73.-	
1	reed loaf basket 10"x6"x3"	K04	2	3.25	1
2	pull spring scales, max. 5 N	60418-01	1	8.95	4
1	Boyle's law apparatus	64710-00	1	11.25	
1	replacement cap	64710-01	1	1.95	2
1	replacement syringe	64710-02	1	5.75	2
1	Charles' law tube	61052	1	22.70	
1	equilibrium tubes	61609	1	34.75	
1	Pascal's demonstrator	45517	1	23.95	
1	demonstration manometer	68956	1	74.-	3
1	set rubber Magdeburg hemispheres	62279	1	18.50	
1	fire syringe	64755	1	19.50	
1	clear plastic box 2.5"x2.5"x1"	104	2	0.40	
1	supply of small cotton balls		3		5
1	graduated pitcher 500 ml,	64343-05	1	6.10	
1	graduated pitcher 1000 ml	64343-10	1	7.60	
1	volumetric flask, 500 ml	46707-15	1	18.75	
1	rubber stopper, 2 holes (Twistit stopper assortment black)	45117-00	1	13.95	11
1	L-shaped connecting tube, outer diameter 6 mm	45227-01	1	1.20	10
1	thermometer, red alcohol, -20 °C – 110 °C	63320-00	1	4.95	
2 ft.	plastic tubing, inn.dia. 4.6 x 1.6 mm wall (=3/16" x 1/16")	62900-02F	1	7.50	3
1	small aluminum cup		3		7
1	piece of wood, ca. 5x5x5 cm, a small hook attached		4		7
1	support stand: black base w/ rod 61 mm	63080-03	1	16.95	
1	clamp, right angle	61120	1	7.95	
1	horizontal rod (wood dowel, 10 cm, 10" long)		4		
1	extension condenser clamp 50 mm Jaw opening	61110-02	1	14.90	6
1	hot plate, single burner, 700 W	62070-00	1	32.90	
1	extension cord		3		
1	clear plastic box 2.5"x2.5"x1"	104	2	0.40	
5	hooks, s-shaped, small (ca. 5 mm loop diameter)		4		8
1	bicycle pump		3		
1	set of air balloons, ca. 15 – 20 cm if blown up (toy store)		3		
1	large tray (ca. 45 x 60 cm)		3		9
1	disposable funnel (in Qty. Of 10)	69501-03	1	5.95	

Sources:

- 1) Science Kit & Boreal Lab., 777 East Park Dr., Tonawanda , NY 14151, T: 800-828-7777
www.sciencekit.com
- 2) Montessori Services, 228 South A. Street, Santa Rosa, CA 95404, T: 707-579-3003
- 3) Hardware store, office supply or other retailer
- 4) Hand-made

Footnotes:

- 1) The boxes are listed before the items that are put into them.
- 2) Replacements are necessary only over the long run.
- 3) Ca. 60 cm (2') of the plastic tubing is connected to the nipple of the manometer. It is used to blow in or to connect to the flask. To widen the end of the tubing, hold it in hot water, then widen it with pliers/clippers.
- 4) If these spring balances come with 2 scales (dials), one in Newton, one in grams:
Please cover up the scale in grams, since spring balances do not measure mass, they measure force.
- 5) A cotton ball is used with the fire syringe. It will burn up each time the syringe is used.
- 6) This clamp will hold the flask.
- 7) The 2" aluminum containers of tea warmer candles, or from canned tuna, work fine. It will be dumped in water: When dumped sideways, it will go under, when set upright, it will swim.
The piece of wood will swim anyway. Both, cup and wood, should fit the pitcher, to measure its water displacement. The wood should be varnished to withstand water. The hook is needed to hang it on the spring scale.
- 8) Make from electric wire # 12, remove insulation, wind around dowel, bend up into s-shape.
- 9) The large tray is to catch spills. Buy at a restaurant supply store.
- 10) The connecting tube is needed, to connect the hole in the rubber stopper (on the flask) and the plastic tubing (that connects to the manometer).
- 11) The stopper must fit the mouth of the flask. It must have 2 holes, one to insert the L-shaped connecting tube, the other to insert the thermometer (use glycerin to ease the sliding-in). The assortment is handy if you can't try the stopper before you buy it. The twistit feature means, the holes are still closed with rubber caps, which you twist off as needed. That way you choose a stopper with three holes, but twist off only two of them.

LIQUIDS/GASES: PRESSURE/VOLUME/TEMPERATURE

1/06

Code on the cards

LG = Liquids and Gases

First number:

- 1 = level one: Sensorial experience (age 6 – 7 years, if children are older follow immediately with level 2)
- 2 = level two: Measuring and calculating (age 8 and older)

Second number: A running number of the experiment

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PGS

Liquids/Gases

LG 1.1

1. Sensorial Experience

1. The Concept of Pressure: Influence of Force

Materials: Boyle' Law Apparatus, set of weights

Commands: 1. Put a 1 kg weight piece on the platform. Observe the platform to go down.
2. Put a 500 g weight piece on the platform. Observe.
3. Put the whole weightset on the platform. Observe.

Statement: When a weight piece is put on the platform, it goes down a bit, with less weight, it goes down less, with more weight it goes down more.

Explanation: Inside the piston the force on the platform creates **pressure**, which presses the air inside the piston together.
The pressure is more, when the force is greater, and less when the force is less.

PGS

Liquids/Gases

LG 1.2

1. Sensorial Experience

2. The Concept of Pressure: Influence of Area

Materials: Pascal's Demonstrator, set of weights

Commands: 1. Set a 1 kg weight piece on the larger piston. Press down on the small piston.
2. Set a weight piece on the the small piston that just balances the 1 kg.
3. Set the 1 kg on the small piston, press down on the large piston.
4. Set a weight piece on the large piston, that just balances the 1 kg.

Statement: The forces pushing down on the pistons are different. The force on the small piston is smaller, on the larg piston greater, if the system is balanced.

Explanation: The pressure is higher when the force is greater, but it is lower when the area of the piston is larger. **Pressure is Force per unit of area.** If the area has more unit squares (as in the larger piston) the force is divided between more units of area, so the pressure is smaller. In the setup, the pressure is the same in both syringes, so the forces are different

PGS**Liquids/Gases**

LG 1.3

1. Sensorial Experience

3. The Concept of Pressure: The Magdeburg Hemispheres

Materials: set of 2 Magdeburg rubber hemispheres,

Commands: 1. carefully match the 2 hemispheres, press them together, so that there is no air in between.
2. try to pull them apart.

Statement: It feels, as if a giant force is keeping them together

Explanation: The air pressure of the surrounding air presses the hemispheres together, since there is no air inside to press against.
Since the area of the hemisphere is large, the resulting force is also large.
This experiment was first designed by Otto von Guericke (-1686), who used 2 copper hemispheres 44 cm diameter, evacuated with a pump: 8 horses on each side couldn't tear them apart.

PGS**Liquids/Gases**

LG 1.4

1. Sensorial Experience

4. The Concept of Pressure: The Bicycle pump

Materials: a bicycle pump

Commands: 1. pump air by agitating the pump
2. hold your thumb on the hole to stop the air flow.
3. Where do you need more force: at the handle (to push) or at the hole (to keep your thumb tight enough so that no air escapes) ?

Statement: More force is needed to push the handle as to hold the thumb on the hole.

Explanation: Inside the pumpo there is a piston, that has an area of approximately $3(4) \text{ cm}^2$. The hole, that the thumb covers, has an area of approximately 1 cm^2 . The same pressure inside the pump produces more force at the larger area (the piston), than on the smaller area (the hole).

PGS**Liquids/Gases**

LG 1.5

1. Sensorial Experience

5. The Concept of Pressure: The Manometer

Materials: Demonstration manometer, plastic tubing, attached to the nipple of the glass tube,
colored water (ca. ¼ liter)

Commands: 1. fill the glass tube with colored water, so that the water level is just under the middle of the glass tubes
2. gently blow into the plastic tubing
3. feel the pressure, created by your lungs, as the water rises in the glass tube

Statement: As the water rises, more pressure is needed.

Explanation: Once the one water level is higher, the weight of the water presses against the air. If the distance between the two water levels becomes greater, more water presses with its weight against the air.
This device can be used to measure the pressure in the plastic tubing: The more pressure is applied, the higher the water level will rise.

PGS**Liquids/Gases**

LG 1.6

1. Sensorial Experience

6. Pressure works in all directions

Materials: A plastic bottle with holes in all directions, tape, water, a basin to catch spills, A drinking glass, a postcard.

Commands: 1. Tape the holes in the bottle, fill the bottle with water
2. hold the bottle over the basin and quickly remove the tapes. Observe*
3. fill the glass with water to the rim, lay the postcard on its top
4. hold the card, turn the glass upside down, let go of the card
5. carefully move the glass over the basin and pull at the card.

Statement: 1.-2. The water pours out of the holes, in all directions (except up)
3.-5. The card stays attached to the glass, no water spills out, when you pull at the card, the water spills out.

Explanation: 1.-2. The water pressure works in all directions. Since the pressure is created by the weight of the water, it does not work upwards.
3-5. The air pressure surrounding us (created by the weight of the air above us) presses also upwards, pressing the card against the glass. If you pull the card loose, the same pressure gets also inside, so the card is pressed from both sides. (Both these experiments are also in your AMI album, but under a different point of interest)

PGS**Liquids/Gases**

LG 2.1

2. Measure and Calculate

1 Formula for Pressure

Materials: Pascal's demonstrator, set of weights, ruler, pen and paper

Commands: 1. measure the inner diameter of each piston, calculate its area
2. put weights on the 2 syringes, so that the setup is balanced
3. calculate the force, brought down by each weight (100g = 1 N)
4. calculate the quotients "Force divided by Area":

$$p_1 = F_1 / A_1 ; \quad p_2 = F_2 / A_2$$

Statement: It turns out that $p_1 = p_2$ (except for minor inaccuracies)

Explanation: Pressure is defined as $P = F / A$

That is "pressure equals force divided by area"

The pressure in both syringes is the same (since they are connected) even if the Forces are different. More force is needed where the area is larger.

The measuring unit for pressure is $[N/cm^2]$

PGS**Liquids/Gases**

LG 1.7

1. Sensorial Experience

7. The Pascal Principle

Materials: set of equilibrium tubes (tubes of different shapes, connected at the bottom), colored water

Commands: 1. fill the water into the tubes
2. As the waterlevel rises, observe the waterlevel in the different tubes

Statement: The waterlevel at every moment is at equal height in each tube

Explanation: This surprising phenomenon was studied by Blaise Pascal, French philosopher and mathematician (-1662), and bears his name.

PGS**Liquids/Gases**

LG 2.2

2. Measure and Calculate

2. The Pascal Principle: Reasoning

Materials: set of equilibrium tubes (tubes of different shapes, connected at the bottom), colored water

Commands: 1. fill the water into the tubes
 2. As the waterlevel rises, observe the waterlevel in the different tubes
 3. measure: The hight of the water over the connecting point
 the inner diameters of the thick and the thin tube
 4. calculate the pressure at the foot of the thick and the thin tube

Statement: We call: A = the area of the footpoint of the tube
 h = the height of the water in the tube
 V = the volume of the water: $V = A \cdot h$
 γ (gamma) = the specific weight of the liquid (for water = 1)
 F = the force of gravity of the water at the bottom $F = A \cdot h \cdot \gamma$
 $p = h \gamma$ p = the pressure at the foot point: $p = F / A = Ah \gamma / A = h \gamma$

Explanation: It turns out, that the pressure at the foot point of the tube is dependent only on the height (h) and the specific weight (γ , the Greek letter gamma).
 No other parameter of the tube goes into the formula!

PGS**Liquids/Gases**

LG 1.8

1. Sensorial Experience

8. Pressure and Volume: Boyle's Law

Materials: Boyle's Law apparatus, set of weights, ruler

Commands: 1. Put 1000 g on the apparatus
 2. observe how far the piston moves further into the syringe (in mm)
 3. put 500 g on the apparatus
 4. observe how far the piston moves further into the syringe (in mm)

Statement: With more weight pressing down, the piston is moved farther into the syringe

Explanation: The syringe is filled with air. The volume of the air is smaller, if the piston is pressed farther into the syringe.
 With constant temperature, the volume (of the air inside the syringe) is smaller if the pressure is larger. The volume is larger if the pressure is smaller.
 This law was studied by Robert Boyle (-1691), an Irish physicist and chemist, and bears his name.

PGS**Liquids/Gases**

LG 2.3

2. Measuring and calculating

3. Pressure and Volume: Boyle's law

Materials: Boyle's Law apparatus, set of weights, ruler

Commands: 1. measure the inner diameter of the syringe. Calculate the area of the piston
 2. put 1000 g on the apparatus
 3. measure the height of the air inside the syringe
 4. calculate the volume of the air inside the syringe
 5. put 500 g on the apparatus, measure and calculate as before
 6. calculate the products $p \cdot V$

Statement: The products are always the same (besides minor inaccuracies*)

Explanation: Boyle's law states that (with equal temperature): $p \cdot V = \text{constant}$
 The constant depends upon the temperature and the kind of gas observed.

*The inaccuracies are due mostly to the friction of the piston. It might help, to move the piston slightly up or down and to take the middle measure of those two marks.

PGS**Liquids/Gases**

LG 1.9

1. Sensorial Experience

9. Volume and Temperature: Gay-Lussac's or Charles' Law

Materials: Charles' Law tube, heat source

Commands: 1. set up the Charles' Law tube. Observe the position of the mercury droplet
 2. heat the tube (i.e. the air inside the tube)*
 3. observe the change in volume of the air inside the tube

Statement: As the air inside the tube is heated, its volume increases.

Explanation: The Volume of the air inside the tube is directly proportional to the length of the air column between the closed end of the tube and the mercury droplet. The increase in length indicates the increase in volume, which is caused by the heat applied to the air inside the tube (by heating the tube)

*heat with a hotplate or immerse in hot oil

PGS**Liquids/Gases**

LG 2.4

2. Measure and Calculate

4. Volume and Temperature: Gay-Lussac's or Charles' Law

Materials: Charles' Law tube, heat source, water container, thermometer

Commands: 1. put the tube into a suitable container with water or oil.
2. measure and note its temperature; note the length of the enclosed gas (note the temperature in °Kelvin: °Kelvin = °Celsius + 273 °)
3. heat the water/oil
4. measure and note as before
5. calculate the quotients "Volume divided by Temperature in °Kelvin":
 V / T

Statement: The quotient is always the same (besides minor inaccuracies)

Explanation: The law, that you discovered, claims, that $V_1 / T_1 = V_2 / T_2$
It claims that if the temperature rises, the volume will rise proportionately.
It bears the name of 2 scientists:
Joseph Louis Gay-Lussac (-1850), French chemist and physicist,
Jacques Alexandre César Charles (-1823), French physicist

PGS**Liquids/Gases**

LG 1.10

1. Sensorial Experience

10. Temperature creates Pressure

Materials: Flask (ca. 500 ml), clamp with swivel jaws, stand with rod ca. 60 cm, clamp and rod ca. 20 cm, heat source, balloon (if inflated ca. 25 cm)

Commands: 1. put the balloon on the flask neck
2. gently heat the air inside the flask

Statement: The the balloon is been blown up

Explanation: The air, as it is heated, increases in pressure, thereby blowing up the balloon

PGS**Liquids/Gases**

LG 1.11

1. Sensorial Experience

11. Pressure increases Temperature

Materials: Bicycle pump,
Fire syringe, cotton ball

Commands: 1. grab the pump around its body, closing the hole with the thumb, with the other hand at the handle press really hard
2. observe the temperature of the body of the pump
3. put the cotton ball inside the fire syringe
4. push the handle fast into the syringe

Statement: 1.-2. the pump heats up
3.-4. the cotton ball catches fire

Explanation: 1.-2. The increasing pressure inside the pump increases the heat of the air in the pump
3.-4. The increase in pressure of the air inside the syringe causes heat

PGS**Liquids/Gases**

LG 2.5

2. Measure and Calculate

5. Pressure and Temperature

Materials: Flask (ca. 500 ml), clamp with swivel jaws, stand with rod ca. 60 cm, clamp, rod ca. 20 cm, heat source, open manometer, colored water in pitcher plastic tubing, stopper with 2 holes, L-shaped connector

Commands: 1. close the flask with the stopper, through one hole push the thermometer
2. in the other hole push the L-shaped connector,
3. fill the manometer with the colored water so that the water level is slightly under the middle of the tubes. Note that position of the water
4. with the plastic tube connect the flask with the nippel of the manometer
5. gently heat the air inside the flask.
6. note the temperature of the air inside the flask (in °Kelvin = °Celsius + 273 °)
7. note the distance of the water levels (a measure of pressure)
8. calculate the quotients “pressure divided by temperature”: p / T

Statement: The quotient is always the same (with equal volume, e.g. if the increase in volume due to the volume change inside the manometer is negligible)

Explanation: The law, that you discovered, claims, that $p_1 / T_1 = p_2 / T_2$
It claims that if the temperature rises, the pressure will rise proportionally.

PGS**Liquids/Gases**

LG 2.6

2. Reasoning

6. The General Gas Law

Materials: The results of cards 2.3, 2.4, 2.5

Explanation: If we unite the laws discovered in 2.3, 2.4, 2.5, we arrive at the

General Gas Law:

$$p_1 V_1 / T_1 = p_2 V_2 / T_2$$

All these laws are correct for what are called “ideal gases”.

At or near the point, where a gas turns liquid, these laws are no more valid.

If we would calculate the Volume at $T_2 = 0 \text{ }^\circ\text{K}$ (= - 273 $^\circ\text{C}$, the absolute zero temperature), the above law would approximate a volume of zero. That of course is not possible. The reason for this contradiction is: At the absolute zero temperature no substance would be a gas, but a solid. So the gas law would not be applicable.

PGS**Liquids/Gases**

LG 1.12

1. Sensorial Experience

11. Buoyancy

Materials: Basin with water, set of weights, piece of wood (ca. 5 • 5 • 5 cm), small aluminum cup

Commands: 1. put the 500g brass piece into the water; observe, take it out
2. put the wooden piece into the water; observe, take it out
3. put the aluminum cup into the water (sideways!); observe, take it out
4. put the aluminum cup into the water (with the bottom down!); observe, take it out

Statement: The brass piece does goes down in the water, the wooden piece floats, the aluminum cup, if placed sideways, goes down, if placed bottom down, it floats.

Explanation: The water pushes up on the submerged piece. This upward force is called **buoyancy**.

The buoyancy is determined by the water displaced by the object.

The brass piece and the aluminum have more mass than the water displaced.

The aluminum cup, set bottom down, displaces more water than the volume of its metal body, because the displaced volume also contains air inside the cup.

PGS**Liquids/Gases**

LG 2.7

2. Measure and Calculate

7. Buoyancy

Materials: Graduated pitcher (500 ml) with water, set of weights, spring scale 5 N, piece of wood (ca. 5 • 5 • 5 cm), small aluminum cup

Commands: 1. Calculate and note the gravitational weight of the 500 g piece in Newton
 2. submerge the 500g piece in the water, measure its weight w/ a spring scale
 3. measure the volume of the displaced water (the difference in the water level)
 4. calculate and note the weight of the displaced water (specific weight of water is 1)
 5. do the same with the wooden piece and the aluminum cup

Statement: The brass: The decrease of the weight in the water is the same as the weight of the displaced water.
 The swimming pieces: The weight of the displaced water is equal to the weight of the piece.

Explanation: This law of buoyancy bears the name of Archimedes (-212 B.C.), the greatest physicist, mathematician and engineer in antiquity.
 In case of the swimming cup, the amount of water displacement is increased by the hollow shape, as in ships and buoys.

PGS**Liquids/Gases: Buoyancy**

LG 1.13

The Story of Archimedes:

The Greek philosopher, engineer and mathematician Archimedes (died 212 BC) was, among others, deeply involved in experiments with the volume of solids, like spheres or irregular solids.

One day, Hiero the king of Syracuse, requested his help: The king had given a lump of gold to a goldsmith to make him a new crown. When the crown was delivered, the king wondered, if the goldsmith had used all the gold given to him. Maybe he had cheated the king and kept some of the gold to himself. Archimedes weighed the crown, it was the correct weight of the lump of gold. But the goldsmith could have taken away some of the gold and replaced it with another, more light weighted material, like copper. So the weight of the crown would be the same. Only the volume of the crown would be larger than the volume of the lump of gold.

How was Archimedes to determine the volume of the crown?

Archimedes really tried hard to solve this problem. He pondered so hard, that in the end he was exhausted. He decided to take a bath.

When he climbed into the bath tub, he observed something remarkable: He saw the water level rising as he lowered his body into the water.

There he knew, how to measure the crown's volume!

He was so excited, that he jumped out of the water, ran, naked as he was, through the town's streets straight to the king, and shouted: "Eureka!!" (which in Greek means "I have found it")

Yes, that's how excited you can get over measuring volume!