**Physics: 5. Pressure**

***Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier***

**Questions to make you think**

1. A heavy crawler tractor is able to operate on soft, muddy ground but the (much lighter) farmer can sink up to his knees in the mud. Why?
2. We will see when we study the chapter on *Heat* that water boils at 100 0C at *normal* atmospheric pressure.

Can you explain *why* it will boil at a temperature less than 100 0C if the atmospheric pressure is low?

1. Can you explain, without using the words ‘pressure’ or ‘suck’, why liquid (e.g. coke) rises up through a straw when you drink?
2. You must have noticed while pouring a liquid into a bottle through a funnel that you have to lift the funnel from timeto time when the liquid collects in the funnel and does not flow down. Do you know why?

**Syllabus**

**OP10** State the relationship between pressure, force and area; perform simple calculations using this relationship

**OP11** Investigate the relationship between pressure and depth for a liquid

**OP12** Show that air has mass and occupies space

**OP13** Associate change in the pressure exerted by the atmosphere with change in altitude

**OP14** Examine weather charts to observe variations in atmospheric pressure and relate these to weather conditions

**Student Notes**

$$Pressure=\frac{Force}{Area}$$

Pressure is caused by a force that pushes against an object.

The pressure increases when the force increases or when the area (that the force is acting on) decreases.

The unit of pressure is the pascal (Pa).

You can also use the N/m2 or N/cm2.

**Example 1:**

The wind exerts a horizontal force of 1000 N on a wall of area 20 m2. Calculate the pressure at the wall.

Answer: P = F ÷ A = 1000 ÷ 20 = 50 pascals.

**Example 2:**

A lady weighs 800 N and is standing in a pair of stiletto heels, each of area 2 cm2.

An elephant weighs 27000 N and the total area of its feet is 1800cm2.

Which exerts more pressure on the ground – the lady in stilettos or the elephant?

Answer

Total pressure exerted by the lady’s (two) feet = 800 ÷ 4 = 200 N/cm2

Total pressure exerted by the elephant’s (four) feet = 36000/1800 = 20 N/cm2

The lady exerts ten times more pressure on the ground than the elephant.

**Pressure in Liquids: the pressure in a fluid increases with depth**

**Demonstration**

Set up as shown.

The water coming out of the bottom hole travels the farthest, because it is under the greatest pressure.



**Air has mass**

**Demonstrations**

1. Can you explain what’s going on in this diagram?
2. Weigh an empty plastic bottle (with the top on) and note the mass.

Pump air into it and weigh it again. Note the new mass.

Result: there was an increase in mass as a result of pumping air in, therefore air has mass.

**Air occupies space**



**Demonstrations**

1. Can you explain what’s going on in this diagram?
2. Glue some cotton wool to the bottom of a glass (inside).

Turn the glass upside down, submerge it completely into a large bowl of water and then remove it again.

Notice that the cotton wool is still dry.

Conclusion: the water could not enter the glass because there was air already in there.

**Atmospheric Pressure**

**The atmosphere exerts pressure**



The atmosphere is made up of giggling atoms and exerts a huge amount of pressure on all objects, including the earth

**Demonstration**

Use a large metal drum and pump the air out using a vacuum pump.

The drum will collapse (implode) because there is now a greater pressure outside acting inwards than there is inside acting outwards.

**Atmospheric pressure varies with height**

Atmospheric pressure decreases as the height above sea level increases (because there is less air overhead).

**A barometer measures atmospheric pressure**

**Atmospheric Pressure and the weather**

****Areas of high atmospheric pressure are represented on a weather chart by the letter H and will normally have dry, clear, settled weather.

Areas of low atmospheric pressure are represented on a weather chart by the letter L and will normally have cloudy, windy, wet weather.

**Why is low atmospheric pressure associated with bad weather?**

Low atmospheric pressure means that it is easy for water to evaporate into the air (because the ‘blanket’ of atmospheric pressure pressing down on the water is lighter)

This results in more clouds and therefore more rain.

**Exam Questions**

1. [2006 OL] [2009 OL][2010 OL][2012 OL]

Give the formula for pressure.

1. [2012] Define *pressure*.
2. [2006 OL][2010 OL][2012 OL]

Name an instrument used to measure atmospheric pressure.

1. [2009 OL]

If a metal block applies a force of 20 N on an area of 5 cm2, find the pressure being applied by the block.



1. [2010 OL]

If the area of the face of a metal block is 30 cm2 and the force (weight) of the block is 90 N, find the pressure being applied by the block.

1. [2010]

The diagram shows a tank full of water. The mass of the water in the tank is 48 000 kg.

Calculate the approximate pressure that it exerts on the base of the tank.

Give the units of pressure with your answer.



1. [2009 OL] [2012]

Three holes were made in a carton of milk at the same time.
2. From which hole will the milk pour out at the greatest rate?
3. Give a reason for your answer.
4. [2010 OL]

A household water supply has a water tank in the attic.

The water pressure at the upstairs tap is lower than at the downstairs tap.

Give a reason why this is the case.

**Atmospheric Pressure**

1. [2011]

The Earth’s atmosphere seen from space is the thin curve at the top of the photo.

1. Name the force that holds the atmosphere to the Earth.

This force gives the atmosphere weight and causes atmospheric pressure.

1. Define pressure and give the unit for pressure.
2. Why does atmospheric pressure decrease with height?



1. [2007]

The diagram is an Atlantic weather chart.

1. Use the chart to predict two *weather conditions* that you might expect for Ireland.
2. Explain why low atmospheric pressure *causes* one of the weather conditions that you have given.

****

1. [2010]

The apparatus shown in the diagram was used to investigate the expansion and contraction of a gas.

1. What is observed when the flask is heated?
2. Explain your observation when the flask is heated?
3. What is observed when the flask is allowed to cool?
4. Explain what you observe as the flask cools.
5. [2009]

The diagram shows a model of the human breathing system.

1. Name the part of the breathing system represented by the balloons.
2. What is the part of the breathing system represented by the bell-jar?

**Exam Solutions**

1. Pressure = Force ÷ Area
2. Pressure = Force ÷ Area
3. Barometer
4. Pressure = Force ÷ Area = 20 ÷ 5 = 4 Pa
5. Pressure = Force ÷ Area = 90 ÷ 30 = 3 Pa
6. The mass is 48000 kg and weight (which is the force) is mass × 10 = 480000. The area is 2 × 2 = 4 m2.

Pressure = Force ÷ Area = 480000 ÷ 4 = 120000 Pa

1. The hole at the bottom – it is under the greatest pressure.
2. Pressure increases with height and the water in the upstairs tap is higher up (closer) to the tank in attic.
3. Gravity
4. Pressure is force per unit area

Pascals (Pa)

1. Less air above/ less weight of air
2. Any *two* from: cloudy/ windy/ rain…
3. Any *one* from: air rises/ air moves in/ water vapour condenses (cools)
4. Bubbles of air come out of the bottom of the glass tube.
5. The air in the flask expanded.
6. The bubbles stop and water rises up the glass tube.
7. Air in flask contracted therefore the air pressure is less than atmospheric pressure.
8. The lungs
9. The rib-cage

**Other Test Questions**

1. Calculate the pressure exerted on the floor by a wooden box, which weighs 48 Newtons if the dimensions of the base of the box are 2m by 4m.
2. An army tank can travel across wet land if it has tracks on, but not if it is on wheels. Explain why.
3. Draw a labelled diagram of the apparatus you would use to show that pressure in a liquid increases with depth. Include in the diagram the results you would expect to see.
4. Draw a labelled diagram of the set-up used to demonstrate atmospheric pressure.
5. What is the relationship between weather and atmospheric pressure?

**Pressure and boiling point**

1. What is the effect of increased pressure on the boiling point of water
2. How would you demonstrate that pressure affects boiling point?
3. Why does increased pressure affect the boiling point of water?
4. Can you think of an application of this (a device which is built on this principle)?
5. Can you think of anyone where this might be a problem?

**Teaching *Pressure***

**The chapter on pressure is really made up of three separate sections:**

1. The mathematical relationship between Force, Pressure and Area
2. Pressure in liquids
3. Atmospheric Pressure
4. **Syllabus: Understand the relationship between pressure, force and area; perform simple calculations using this relationship**

**Pressure = Force / Area**

* Which is more painful on your foot - an elephant stepping on it, a heavy man wearing runners, or a young girl wearing stilettos?
* To answer you need to consider two things; the weight acting down on your foot (the force) and the area over which the force is exerted.
* To consider how these two concepts are related we need a new quantity which we call *Pressure*, where pressure is defined as force divided by area.
* Attach a weight to a string and let it hang off your finger. Now lay a penny on your finger and let the string hang over it. Notice the difference. Same force exerted over a greater area means less pressure on any given point.
* A wide strap for your school bag is much more comfortable that the same bag with just a cord attached.

**To measure the pressure exerted by different objects on the ground**

The blocks can be obtained from the resource room

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Object | Mass(kg) | Weight(or Force)= Mass x 10(N) | Area of Base*Length* x *width**Or π r2*= \_\_\_\_x\_\_\_\_(cm2) | Pressure= Force/Area(N/cm2) |
| Science work-book |  |  |  |  |
| Wooden Block Side A |  |  |  |  |
| Wooden BlockSide B |  |  |  |  |
| Wooden BlockSide C |  |  |  |  |

**2. Syllabus: Investigate the relationship between pressure and depth for a liquid**

**Pressure increases with depth**



There is a special apparatus to demonstrate this with holes a quarter of the way up, half way up, and three quarters of the way up.

You should demonstrate this over a sink, but you might also have a tray handy to collect any extra water.

I have left a length of rubber tubing (from a Bunsen) in the box. Connect it to a tap to allow you to keep the water level in the bottle constant.

It may also be helpful to set the apparatus on a height and have lots of newspaper handy for the inevitable splashes.

1.

**Atmospheric Pressure**

**Syllabus: Show that air has mass and occupies space**

Because atmospheric pressure can only be understood in terms of the movement of air molecules, it is necessary to first introduce the concepts of air taking up space and having mass.

**3.1 To show that air occupies space**

* Stuff some cotton wool to the bottom of a small beaker, then invert it and submerge it in a larger beaker containing water. The wool remains dry.
* Turn a round-bottomed flask so that the mouth is horizontal and facing you. Take a small piece of paper (or table-tennis ball) and place it on the inside wall of the flask. Try to blow the paper into the flask (use a straw if you wish). It actually flies out because the air in the flask compressed against the back wall and sprang back, pushing the paper out with it (think of the air as a jelly-like substance).
* Submerge the syringe provided into a beaker of water and half-fill the syringe. Take the syringe out of the water and suck up air such that it takes up the other half of the syringe. Now slowly squeeze the syringe and observe that the air pushes the water out ahead of it. This is easier to observe and therefore more impressive if the water has some food-colouring in it.
* Many liquid containers (e.g. tetra pak) have two holes which help the liquid to pour out smoothly; one for the liquid out, the other to allow the air to get in without disturbing the flow of liquid heading out. Try to empty a two-litre bottle of water and see how long it takes. A much quicker method is to create a ‘mini-tornado’ where the air goes up the middle as the water goes down the outside. I have included in the box a special plastic connector and two small bottles. Shake in a circular fashion to start it off. The troops think it’s impressive!

**3.2 To show that air has mass**

Inflate a balloon and weigh before and after. Text-books don’t mention this but you should be very careful with this one. Remember that the weighing scales is weighing all the air above it, regardless of whether or not this air is in the balloon. There is a danger that students may think that the *only* air present is in the balloon. The demonstration works due to the increased air pressure inside the balloon; there are more air molecules in the balloon per unit volume than there is outside. Personally I tend to avoid this demo altogether.

**Alternative**

Using a standard plastic pop bottle, a mass balance with 0.1 g resolution, and a pump specially designed to fit on these bottles, called a ‘fizz-keeper’ – available from the Physics Lab. The fizz-keeper is available for a couple of euro from www.teachersource.com.

**Mass:** 10 'pumps' increases the mass by 0.1g without any significant change in volume.

Don’t over-pump or the fizz-keeper will break.

**Syllabus: Understand that the atmosphere exerts pressure and that atmospheric pressure varies with height**

**3.3 To demonstrate atmospheric pressure**

* Fill a gas jar with water and place a beer-mat on top. Invert the gas jar and take your hand away from the mat.

The beer-mat and water is held up due to atmospheric pressure pushing up on the beer mat. This is typical of what we do in physics – everybody learns the demo yet few if any discuss *why* the pressure is less inside.

* The imploding coke can*.*

Insure that the can is inverted when dunking it in the water. Use a glove or tongs to hold the can.

Why do the cans have water in them after implosion? *Get your own supply of cans in advance!*

* Use a bell-jar with a balloon and marshmallow.

These inflate when the air is withdrawn – there is more pressure inside these materials (in the form of bubbles) than there is outside. When you let the air back in they shrink back to less than their original size because some of the air which was inside the material has escaped.

To make it even more impressive, use shaving foam instead of (or along with) the balloon.

* Get a hard-boiled egg and create a partial vacuum in a round-bottomed flask by burning a piece of paper in the flask and placing the egg on top. Watch as the egg gets sucked into the flask. It may be useful to rub Vaseline around the top of the flask. It can be a bit finicky so practise in advance. Alcohol soaked in cotton wool is useful to burn up the air

Where does the air actually go?

* Try drinking water through a straw which has a tiny hole in it. Why doesn’t it work?
* Demonstrate the principle of vacuum-packing. Stand a student in a large bin-bag. Get the student to tape the top around themselves and also to stick the end of a hoover inside the tape. It is great fun but can be embarrassing so it’s best to let the student try it themselves with just their friends first.
* Play with a syringe; various ways of demonstrating relevance to pressure.

**3.4 Understand that atmospheric pressure varies with height**

* The Irish scientist Robert Boyle was one of the first to investigate/appreciate atmospheric pressure. He declared that we were all ‘living under a sea of air’. I think of us as being the equivalent of crabs moving around the bottom of this jelly-like substance. When we make a sound for instance all this air vibrates just like jelly would when smacked.
* If you wanted to dive to the bottom of the ocean you would need to wear a metal suit to prevent getting crushed.
* Similarly bottom-dwelling fish could not survive on the ocean surface. Some fish can adapt to the different pressures, but I’m not sure how; I guess by somehow adjusting an internal air-ballast system.

**3.5 Examine weather charts to observe variations in atmospheric pressure and relate these to weather conditions**



High atmospheric pressure means there is a greater density of air molecules present than would normally be the case. This means it is difficult for water molecules to ‘jump’ into the air; it is as if there is a heavy blanket lying on top of the water.

Another important feature to meteorologists is whether or not the atmospheric is changing. Air will move (in the form of wind) form areas of high pressure to areas of low pressure. This will also increase evaporation and unsettled weather, particularly in the low-pressure areas.

Less water molecules in the air means fewer clouds which in turn means

1. Dry, bright days
2. Warm in summer because there are no clouds to block out the sun
3. Cold in winter because clear skies allow heat from the earth to be re-radiated back out into space.

**By the way, did you know that you actually suck after all?**

When you suck up water what is actually happening is that you are expanding your diaphragm to lower the pressure/create a partial vacuum inside your body. Atmospheric pressure then presses in on the bottle and the water rises by what I call *the bean-bag effect* (two people press down on either side of a bean-bag and the middle rises up). Alternatively if you are drinking a glass of water through a straw the atmosphere presses down on the water and it rises up in the middle by the bean-bag effect.

Aircraft are pressurised, which explains why passengers get ‘sucked out’ of a plane if the door gets blown off at high altitudes.

If a large truck passes you out at speed (if you’re walking or cycling) you can get ‘sucked in’ to its slip-stream.