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For Primary Schools and Teachers of S1/S2 courses

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It doesn't work - it must be physics

Thomas Edison

"Results! Why, I have gotten a lot of results. I know several thousand things that won't work".
"Just because something doesn't do what you planned it to do doesn't mean it's useless."

Thomas Edison 1847 - 1931

We should all take heart from the above quotes by Edison, one of the most prolific inventors and experimenters of the last two centuries. Science is about questions. It's about investigating ideas or hypotheses. It's not about 'right answers'. Nor is it simply about teacher demonstrations to prove some 'scientific fact'.

"Children share with geniuses an open, inquiring, uninhibited quality of mind."

Chauncey Guy Suits 1905-1991. One time Director of the General Electric Research Laboratory.

Look around the classroom on a cold Monday morning in October and we may not recognise the truth in the third of our quotes. Trite as it may sound, it is, and should be, memorable. Children, as do we all, have misconceptions about the world around them and their 'alternative' views of the world are based on their own experience. Such ideas are hard to shake. That this is so is often evident in their learning in science. Therefore we should ensure that pupils are encouraged to investigate their own conceptions, challenge them and seek alternatives. With a little luck, their newfound understanding will be based on guided observation and investigation.

This brings us eventually, if not neatly, to the main topic of this Newsletter. We have a concern that teachers are too often being mis-directed by those who really should know better. Publications that offer ideas for investigations, activities to challenge misconceptions, or to demonstrate a key scientific idea, are commonplace in print and on the web. If so published, they should be tried and tested. Unfortunately a few seem to be based on theory and have never been exposed to a practical test. How often has the cry been heard "It doesn't work. It must be me. There's something I'm not doing properly!" It ain't necessarily so. Remember Edison and consider the following examples.

Time and Tide

"Go, measure earth, weigh air, and state the tides!" *(Alexander Pope)*

Most young children believe that a balloon full of air is lighter than an empty one – probably as a result of the tearful loss / joyous sight of the helium-filled balloon inadvertently / deliberately released from grubby little hands. Well, air is light stuff, isn't it? How do we challenge such an idea? We could try a theoretical approach.

The pressure of air at sea level is approximately 10 N (Newtons) for every square centimeter (10 Ncm^{-2}) – kind of like the force with which a 1 kg bag of sugar would press down on each and every key of a standard computer keyboard. Try working out how many square centimeters you have pointing upwards (mine is approx. 42 x 18 = 756 cm^{-2} - funnily enough just about the area of the aforementioned keyboard) and that is quite a weight on your shoulders (7560 N to be precise). This is the force with which all that air presses down on your back. Imagine we had a very large beam balance and we could put a column of air extending to the top of the Earth's atmosphere on one balance pan and a column of say, mercury (a very dense liquid metal) on the other. How much mercury would we need to balance the weight of air? Well, . . . you get the point, hopefully, but if not here we go.

The density (mass per unit volume) of air is about 0.0012 gcm^{-3} (grammes per cubic centimetre) at sea level. Mercury has a density of 13.6 gcm^{-3}, roughly ten thousand times that of air. This means we would need one thousand times less mercury to balance our scales. Air becomes less dense the higher you climb or fly. The force exerted by the Earth's atmosphere comes mainly from that body of air extending up to about 10 kilometres above sea level. A wee sum will show that (very roughly) a one metre column of mercury has a weight that would be needed to balance the force of a ten kilometre column of air of the same diameter.

If the 1 metre column of mercury has a radius of 1 cm it will contain 3,141 cm^3 (volume = radius squared times the height times π [Pi]). This has a mass of about 42.716 kg (3,141 x 13.6 g [density of mercury]). Since the columns balance, the 10 km of air must have the same mass as a one-metre column of mercury. This is the theory behind the mercury barometer.

Is this too much for most seven to ten-year olds? You betcha!

So we turn instead to a widely published demonstration using balloons and a wire coat hanger (Fig.1). Nothing could be simpler, especially the apparatus - two balloons, a coat hanger and some string or a couple of clothes pegs. One balloon is blown up to as large a diameter as possible. It is then suspended from one arm of the coat hanger. The uninflated balloon is placed on the other arm. Balance the hanger by the hook and 'Hey Presto' we have a beam balance. Showing what exactly? The theory is that the balloon with air will be the heavier and will drop dramatically. We have tried this many times with a pack of supermarket balloons and a wide variety of coat hangers. We can report little success. There's no dramatic movement, and no 'Wow' factor (to use a current cliché). However, if you have had success with this we'd be delighted to hear from you (he wrote, not without irony).

Fig.1 - Coat hanger balance?

Then, using an electronic balance we weighed an 'empty' balloon and another inflated to almost bursting point. This exercise was repeated and the usual difference was about 0.3 g. This is not a difference detectable on the types of balance usually found in primary schools. There are other worthwhile investigative activities of this type. They all rely on the use of a fairly sensitive, electronic balance and also involve the use of special air pumps and other types of container. As such, they are thus much better suited to work at the secondary stage.

Simple methods, such as detailed above, with its misguided use of a coat hanger, often ignore confounding factors. In this case, these include such matters as water vapour and carbon dioxide in the balloon - should exhaled breath be used to 'fill' it? It also ignores the effects of buoyancy and the fact that each balloon will displace its own volume of air (good ol' Archimedes). Therefore, it's not faulty physics but flawed experimental design, which is the problem here. Primary teachers and their pupils deserve better. They can make their own mistakes and they don't need or want help from authors and publishers to make more.

Where do we go from here? Well we've argued theoretically to show that a column of air does have mass. How could we show this?

Feeling the pressure?

Another way of 'weighing' the air is to measure atmospheric pressure, using a barometer. We'll use the balloons this time for a different purpose. This is another idea that has been widely published but, this time, it usually 'works'.

Take one of the balloons left over from the coat hanger debacle. Remove the 'neck'. Stretch the balloon (Fig.2) over the mouth of a jam jar or similar container (we used an empty pillbox from the local pharmacy). Put sticky tape around the balloon and the container, to keep everything airtight and tidy. Finally, glue a drinking straw to the centre of the stretched balloon. Test the glue on the material before attaching the straw. We used good old-fashioned *Gloy*. The picture in Fig.3 shows the finished barometer. This has a plastic ruler as a scale to read changes in pressure (the force per unit area exerted by the column of air above the container).

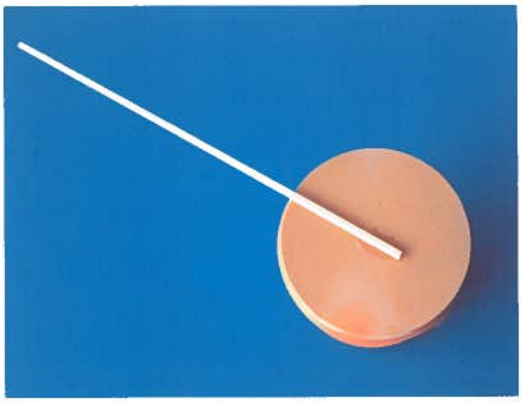


Fig.2 - DIY barometer from above

Fig.3 - Barometer from side

A barometer proper is used primarily as an aid to weather forecasters – this is done by logging trends in air pressure over time. Here, however, we are trying to show that air exerts a force. From there to understanding that air has mass and thus weight is still a bit of a leap, especially at primary level.

Magic Card Tricks

We will end on a more positive note with a collection of activities that may help to reinforce some ideas about air pressure. They also show that, maybe, you can teach a new dog old tricks. Those longer in the tooth may recall favourite uncles entertaining them with such nonsense. These days, we have to cry such tricks "opportunities to introduce cognitive conflict". Eh?

For the first of these old favourites, one that always works well (he said, tempting fate), you will need a piece of card and drinking glass. The open end of the glass has to be completely covered and a post card works well for this. Ask the class what will happen if you fill the glass with water put the card on top and turn the glass upside down? Fill the glass to overflowing, firmly press the card over the open end and invert the glass (Fig.4). If you have tried this before demonstrating and are very confident you could invert the assembly over the head of a pupil (well maybe not, unless you're nearing retirement). The card is held in place mainly by external air pressure with a little surface tension thrown in for luck.

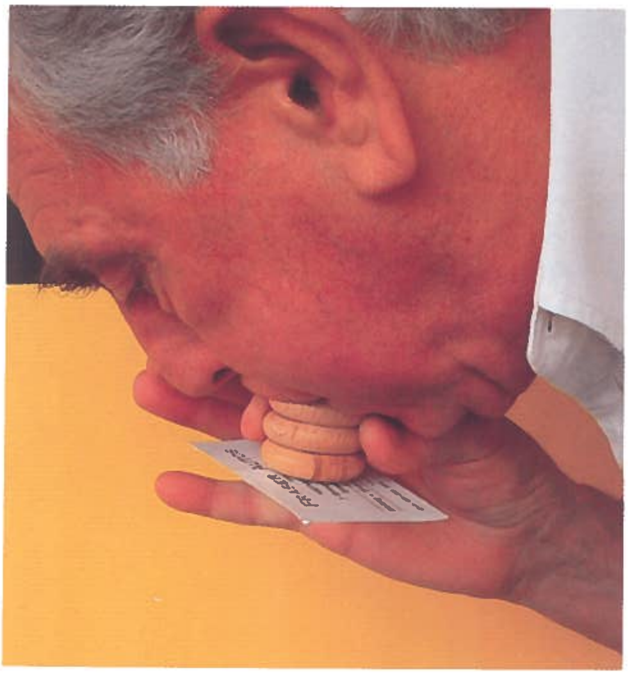
Fig.4 - Don't try this in the local!

Next, crush a paper towel into a small ball and press it into the bottom of a tumbler or a half-pint glass. Ask the class what will happen when the glass is placed in a bowl of water. They will invariably say "the paper will get wet". Hold the tumbler by the base and place it in the water, open end first. Water rises up the glass but should stop before it reaches the paper towel. Try this out for yourself, before you demonstrate it.

Why does the paper stay dry? The air inside the tumbler is compressed and the pressure is enough to stop the water rising high enough to wet the paper.

This last activity was a favourite with one of my more interesting and entertaining uncles. All that is needed is an old-fashioned cotton reel, one with a single hole, not the plastic variety with 4 or 5 holes, and a piece of card about 75 cm x 75 cm. Find the centre of the card by drawing diagonals. Push a drawing pin through the intersection of the diagonals. Place the card under the cotton reel with the pin in the hole in one end and blow hard down the hole in the other. How far can you blow the card?

Surprise! The card does not blow away but stays firmly attached to the bottom of the reel. How can this be?

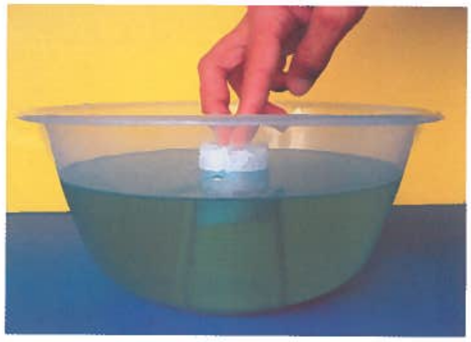


Fig,7 Blown away?

It is all to do with moving air and the differences in pressure it can create. To give it a posh name this is a manifestation of the *Bernoulli Effect*. Put simply, moving air is at a lower pressure than still air. Air escaping from the hole around the sides of the card lowers the air pressure on the inside of the card. The greater pressure in the static air on the other side keeps the card 'stuck' to the bottom of the cotton reel. My uncle assured us it was magic. We all believed him.

It 's in a book, it must be true!

The *balloon and coat hanger* is not the only questionable demonstration that we have found in publications. For example, there are a couple of real duffers on investigating light. One of which uses a glass bowl filled with water. The bowl is placed on a sunny window. A mirror is placed in the bowl at an angle of about 45 degrees, a sheet of A4 paper is set up opposite the mirror. "Eureka!" (to now misquote Archimedes) - a



Figs.5 & 6 Keeping your paper dry?

rainbow, it's claimed, is formed on the paper. The second activity purports to be even easier. On the same sunny windowsill, place a glass of water with its base just over the edge of the sill. A sheet of A4 paper is placed on the floor so that the light from the glass is projected onto the paper. You've guessed it, the light falls on the paper as a rainbow. We have tried both experiments over a number of years with little success. However we recently tried again for this Newsletter and it did work. The reason being we tried around 9 o'clock on an autumn morning when the sun was low in the sky. It would seem the best time to carry out this experiment would be when the sun is not too high in the sky perhaps on a bright sunny winter's day. We've noticed also that you will get the big, semi-circular rainbows early in the morning (Fig.8) or late

Fig,8 Somewhere...over the....

in the evening. As midday approaches the ones you observe are likely to be flatter as only the top of the 'bow is visible. Our advice would be if you want to split light into colours use a prism. They are not too expensive and can be had from most suppliers of primary equipment.

If you disagree with any of this or perhaps have had success with any of the activities criticised here, we would like to hear from you. Equally, if you're having trouble with any investigations from published works, or the web, we are here to help. Such technical support is one of SSERC's major functions. Meantime, if you are forced to choose between the Tommy Cooper repertoire of science tricks and that old uncle's - go for the uncle every time. Science teaches us, amongst other things, to be sceptical. It's just as well.

Annual Conference and AGM of SSERC Limited

Friday 5th November 2004 at Business Learning & Conference Centre, Lauder College, Dunfermline

Programme & Booking Form

9.15-10:00	**Exhibitions open, registration and coffee.**
10:00-10:10	**Welcome and introduction**: Councillor David L. McGrouther, BA, JP, Chairman SSERC Limited, West Lothian Council.
10:10-10:40	***Keynote Address:* 'A National Science Learning Centre for the UK'**
	Professor John Holman, Director, National Science Learning Centre , York.
10.40-11:10	**Improving Achievement in Science Education**
	Dr. Jack Jackson, HMIe, Assistant Chief Inspector and Leader, HMIe Science Team.
11:10-11:40	**Coffee and exhibitions**
11:40-12:10	**PGCE Residential Events & CPD**: John Richardson (SSERC) Jan Barfoot (SIBE) Douglas Buchanan (DUSC)
12:10-12:40	**Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)**
	David Richardson, HM Inspector of Health & Safety
12:40-12:50	**Display Screen Equipment**: Jim Jamieson, Senior Associate, SSERC.
	Closing remarks – Bristow Muldoon MSP
13.00-14.00	**Lunch, Exhibitions**
14.00 on	**Annual Report and General Meeting**
	Board Meeting of SSERC Limited (Directors and Officers of the Company)
	Exhibitions
15.00	**Depart**

I wish to reserve a place at the Annual SSERC Science, Technology and Safety Conference:

Name : ______________________ Position______________Date ________

Address ____

I enclose my cheque/official order* in payment of the delegate fee(s) of £60 + VAT (£70-50) for members*/ £80 + VAT (£94) for non members* [delete if inapplicable]. I wish*/do not wish* a receipt.

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