UNIT 9 Pressure and Gases

Recommended Prior Knowledge

This unit introduces pressure and many pupils will have encountered this quantity in one way or another. By this stage in the course, pupils will already have met the idea of force but, even if they have not, it can be taken on trust prior to its being properly defined. Gas pressure and the pressure caused by solid objects in contact are not, to all pupils, obviously related ideas and it would be useful if some were aware of this connection. Some understanding of the kinetic theory of matter will be necessary in explaining the properties of gases.

Context

This unit contains various ideas which involve pressure and the properties of gases but which are not, at first sight, obviously related. These ideas are useful in mechanics and thermodynamics but to pupils they may well appear to be topics which are not central to the syllabus as a whole. Undermine this impression by emphasising, whenever appropriate, the relationships of the concepts included here to those elsewhere in the course.

Outline

This unit defines pressure and then applies it to situations involving solids, liquids and gases. Two simple pressure-measuring instruments are described and the operation of hydraulic machines explained. At this stage, Boyle's Law is introduced and used. This leads to a more thorough look at gases and how the behaviour of their molecules can explain their properties. Evaporation is re-examined in molecular terms at the conclusion of the unit.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
7(a)	Define the term pressure in terms of force and area, and do calculations using the equation *pressure = force/area.*	Use an inflating balloon to lift weights. Two square holes of different sizes are cut in the flat upper surface of a thin wooden box. A large balloon is placed in the box. The sections which were cut out of the box are placed back in the holes. As the balloon inflates, the small wooden platforms rise up lifting weights placed on them. The larger area platform can lift a larger weight. Show the effect of pressure in experiments. Place heavy cones on sand, both upright and inverted, or construct a "bed" of nails (~25 cm × ~25 cm) and stand on it **carefully**.	Pressure: http://en.wikipedia.org/wiki/Pressure Simple experiments: http://physics.about.com/cs/airandfluidexp/a/040703a.htm	•
7(b)	Explain how pressure varies with force and area in the context of everyday examples.	Many simple examples illustrate the significance of pressure: • the ineffectiveness of a blunt knife, • walking on snow in ordinary shoes – use snowshoes, • a nail or drawing pin has a large area at one end and a smaller one at the other,	Examples: http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/patm.html	

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		• heavy vehicles on soft ground need large area caterpillar tracks, • compare elephants and women in stiletto heels.		
7(d)	Explain quantitatively how the pressure beneath a liquid surface changes with depth and density of the liquid in appropriate examples.	Deduce the formula $p = hdg$ by considering the weight of a certain depth of liquid acting on the base of a tank. Consider specific examples: • the increase of pressure with depth (1 atm. /10 m), • the pressure divers encounter at 20 m • the pressure at a depth of 10 000 m (the Mindanao trench).	Pressure in liquids: http://hyperphysics.phy-astr.gsu.edu/hbase/pflu.html Pressure in the sea: http://encarta.msn.com/encyclopedia_761573707/Bathyscaphe.html	Let water escape out of narrow tubes at different levels in the side of a cylinder of height ~50 cm, filled with water. The lowest jet squirts the furthest. Lower a sensitive pressure gauge into water and observe the reading.
7(c)	Describe how the height of a liquid column may be used to measure the atmospheric pressure.	Consider inverting a 1.0 m tube full of mercury into a small mercury bath (wear thin plastic gloves to prevent mercury absorption through the skin). Calculate the pressure at the base of the column of mercury. It exceeds atmospheric pressure. The mercury flows out of the tube until the pressure of the mercury equals that of the atmosphere. What happens as the atmospheric pressure changes?	Torricelli's experiment: http://fyzweb.cuni.cz/piskac/pokusy/torr/	To make such a barometer with water would need plastic tubing of length 10 m; it is what Torricelli did. It can be done.
7(e)	Describe the use of a manometer in the measurement of pressure difference.	Describe a manometer and make a simple one to measure the excess pressure of the gas main. Measure how hard a pupil can blow. A water manometer will need to be ~3.0 m tall for this.	Manometer: http://www.dwyer-inst.com/htdocs/pressure/ManometerIntroduction.cfm	Pour water into a U-tube. Into one limb pour a less dense liquid. The top levels in the limbs are unequal. This is especially surprising if the second liquid can mix with water (e.g. ethanol).

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7(f)	Describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press and hydraulic brakes on vehicles.	Make a model hydraulic jack with two vertical syringes of different diameters. The syringes are half-filled with oil and their jets joined with tubing (filled with oil – water can be used but forms bubbles of air). Pushing down one piston lifts the other. Use a small weight on the smaller syringe to lift a greater one on the larger syringe. A small force is being magnified. Compare the distances through which the two weights move.	Hydraulic brakes or press: http://www.darvill.clara.net/enforcemot/pressure.htm	Solids transmit forces, whereas liquids and gases transmit pressures. Hand out incomplete or unlabelled diagrams of these devices and let the pupils complete them.
7(g)	Describe how a change in volume of a fixed mass of gas at constant temperature is caused by a change in pressure applied to the gas.	Pupils will know that reducing the volume of a gas increases its pressure. Place a finger over the end of a bicycle pump; it takes a large force to compress the gas. Use a standard piece of equipment to demonstrate Boyle's Law. Consider examples such as: • bubbles released from sinking ships, • the volume of a free diver's lungs at ~70 m below sea level, • partially inflated meteorological balloons released from the earth's surface.	Boyle's Law: http://www.grc.nasa.gov/WWW/K-12/airplane/aboyle.html	Explain the law in molecular terms. In a larger volume the molecular density is lower and so there are fewer collisions with the walls of the vessel per second. The pressure falls.
7(h)	Do calculations using $p_1V_1 = p_2V_2$.			
12(a)	State the distinguishing properties of solids, liquids and gases.	Pupils will be very familiar with these properties. This is a sensible time to tabulate them, include: solids transmit forces; liquids and gases transmit pressures.		
12(b)	Describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces	Show pupils models of solid structures. Balls joined together by springs and balls glued together directly. Use glass beads in a tube with a vibrating base to simulate the three states.	Brownian motion: http://www.phy.ntnu.edu.tw/java/gas2D/gas2D.html Molecular structures:	Calculate or give values for the separation of molecules in liquids

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	and distances between molecules and to the motion of the molecules.	Pupils can act out the behaviour of solids, liquids and gases as they behave like molecules themselves. Show the Brownian motion of smoke particles.	http://www.apqj64.dsl.pipex.com/sfa/slg_structure.htm	and solids. Calculate the separation of molecules in air at room temperature.
12(c)	Describe the relationship between the motion of molecules and temperature.	State as a fact that molecules travel faster at higher temperatures. Molecules in solids vibrate but in gases they travel in straight lines between collisions.	Moving molecules: http://id.mind.net/~zona/mstm/physics/mechanics/energy/heatAndTemperature/gasMoleculeMotion/gasMoleculeMotion.html	Justify the statements: • The speed of sound in air increases with temperature. • The pressure of a trapped gas rises with temperature.
12(d)	Explain the pressure of a gas in terms of the motion of its molecules.	Explain that the collisions of extremely tiny molecules travelling at very high speeds causes many minute impacts whose spread out effect is detected on a macroscopic scale as pressure. A football can be kept in the air by constantly punching it from below. Many tiny impacts cause a single force. Balloons burst as a party progresses, it gets hotter in the room and the pressure in the balloons rises. Gas cylinders explode in fires.	Pressure and temperature: http://www.antonine-education.co.uk/Physics_AS/Module_2/Topic_8/gas_laws.htm	Take a hollow, copper sphere with a pressure gauge attached. The pressure increases with its temperature.
12(e)	Describe evaporation in terms of the escape of more energetic molecules from the surface of a liquid.	The faster molecules escape and so the liquid left behind is cooler.	Evaporation: http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/vappre.html Refrigerators: http://www.wisegeek.com/how-does-a-refrigerator-work.htm	
12(g)	Explain that evaporation causes cooling.	Place a glass beaker or a copper can on another one which is upside down. Put a small amount of water between them.		Cooling by evaporation: • refrigerators • perspiration

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		In the top vessel pour a small amount of a volatile liquid. Force air rapidly through the liquid so that it evaporates quickly. The water freezes and the lower vessel can be lifted up with the upper one.		• panting dogs • wiping ether on an arm before an injection • wrapping butter or ice cream in wet paper.
12(f)	Describe how temperature, surface area and draught over a surface influence evaporation.	Carry out some experiments to determine these effects. Use a volatile liquid or use water over several days.	Rate of evaporation: http://esci.unco.edu/water/wtrwise/2t.htm	♦ How is the shape of a cooking pan determined by what is being cooked? ♦ Why does an evaporating dish have a large surface area? ♦