Integrating Pneumatics into the Science Curriculum

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This curriculum guide marries industrial technology--in this case, pneumatics--with theory, and brings them right into the classroom. It was developed for a ninth grade science class and goes a long way toward helping meet a goal of Project 2061--Science for All Americans, of integrating science and technology with an emphasis on real world applications.

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About the **FPEF**
The FPEF, with the support of the fluid power industry, coordinates, supports and promotes education in fluid power. The Foundation is always striving to raise the level of competence of young people entering our industry and improve visibility for fluid power technology.

Information regarding the "train the trainer" sessions, and other activities of the FPEF are available:

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Today's students' scientific and educational needs are vastly different from those in the past. In a world where technological advances are changing our lives daily, an integration of science and technology in the classroom becomes a necessity. This integration offers a unique opportunity to create science programs that allow the student to experience scientific concepts in addition to their technological applications. A fine example of this is the integration of basic pneumatics into the middle or high school science program.

There are any number of ways that pneumatics may be integrated into either an earth or physical science program. In earth science, a unit on "air" might begin with a unit on:

I. The physical characteristics of air:

- Air takes up space.
- Air has mass.
- There are spaces between air molecules.
- Air's mass and volume determine its density.
- Air density can change.
- Air density is affected by changes in altitude and temperature.
- Warm air becomes less dense and rises while cold air becomes more dense and settles.

II. The weather on Earth results from the presence of air on the earth's surface (atmosphere):
Air is warmed at the equator and cooled at the poles. Winds are produced when cooler, sinking air moves in to replace warmer rising air. (Convection currents and thermals) Major wind systems affected early exploration of the earth. Wind systems and jet streams' direction of movement are affected by the earth's rotation. (Coriolls effect) Large air masses of equal density travel across the earth's surface creating weather patterns.

Air pressure is measured with a barometer and is recorded by meteorologists as isobars on weather maps.

The leading edges of air masses are called fronts. The U.S. Weather Service monitors weather patterns and issues weather reports. Temperature affects the density of air molecules and possible moisture in the air. (Humidity and relative humidity)
A psychrometer may be used to measure relative humidity. When water condenses on dust particles, clouds and precipitation can be produced.

III. Climate results from long-term weather patterns.

- The physical features of the Earth can affect long-term weather patterns.
- The climate we live in affects our life style in many ways.

This unit on "Air" could then flow into a unit on pneumatics demonstrating that "Air Can Do Work" as detailed in the curriculum guide that follows.

Aerodynamics could then be studied demonstrating the forces of lift and drag, Newton's Laws, Bernoulli's Principle and their effects on transportation design. A physical science course could integrate pneumatics in a simple machines unit including pulleys, levers, inclined planes and wheels and axles. Experiments could be designed to measure and calculate mechanical advantage and efficiency of various machines. Real life simple, compound and complex machines would be analyzed to find their component simple machines. Manufacturing facilities could be visited to emphasize how technology builds on basic physical science principles in industrial applications. Life sciences would then become involved by demonstrating the simple machines that make up the human body.

Whichever method is used to incorporate pneumatics into the science curriculum, the goal of creating scientifically literate citizens for the 21st century can best be served by creating a program that provides situations where students work independently and cooperatively in groups using scientific principles to solve technological problems associated with "real-life" situations.

Student Outcomes:	Major Area Of Instruction:	Suggested Activities:
Student will design a method of finding the volume of an inflated balloon. Student will observe a sealed two-liter bottle, one-half filled with water. From their knowledge of density, they will explain why the air sits above the water.	Air takes up space (has volume) and has mass. These can be used to calculate its density.	Lectures, demonstrations and student activities: Fill up a balloon with air. Show an "Air Up" rather than "waterfall" by moving air from bottle to bottle under water. Use displacement to find lung capacity using a rubber hose, an inverted water-filled plastic gallon milk carton in a bucket filled with water. Find the mass of an empty balloon and one filled with air using a balance - understand that the air in the balloon is compressed, thus denser and weighs more.
The student will design a way todecrease the volume of space between gravel particles and then answer the following: 1. Would this increase or decrease the volume of gravel? 2. Would this increase or decrease the mass of the gravel? 3. Would this increase or decrease its density?	There is space between air molecules	Model: Use a beaker containing gravel to show that there is space between the gravel particles by adding water until it is level with the gravel. Use a graduated cylinder to measure the volume of space between the gravel.

Student Outcomes:	**Major Area Of Instruction:**	**Suggested Activities:**
Student will diagram a pop can containing hot air suddenly losing heat and the resulting change in density of air molecules.	Air density can be made to change.	Demonstration: "Imploding pop cans" 1. Heat pop cans with a small amount of water in them on a hot plate until they steam. 2. Flip the cans over into a cake pan holding cold water, holding them with tongs. 3. They will implode. Demonstration: Burn paper in bottle with a peeled, hard-boiled egg in the bottle mouth. Egg will be drawn into the bottle.
The student will describe the changes in density of the water and air in this closed system to explain the Cartesian diver's motion.	Air density can be made to change.	Student Activity: Build a Cartesian diver using a Water-filled, 2-liter plastic bottle, and an eyedropper filled with water to the point where it just floats on the top of the water in the bottle. Screw the top on tightly. 1. Press the sides of the bottle. 2. Release the sides of the bottle. 3. Notice the water level inside the eyedropper as you do each several times. Demonstration: Magdeberg Hemispheres

Student Outcomes:	Major Area Of Instruction:	Suggested Activities:
The student will record barometer and temperature readings at the beginning of class for five periods and go outside to record weather conditions. From these observations, the student will record three relationships they have found between weather conditions, temperature and air pressure supporting each with collected data.	The atmosphere is an "ocean" of air exerting pressure on the earth's surface and everything on it. We can measure air pressure with a barometer. Temperature and altitude can affect the density of free air. Air pressure can be measured in psi (14.7 psi at 60°F at sea level), atmospheres, mm Hg or pascals.	Lecture: Weather including: 1. High and low pressure air masses 2. Convection currents (equator, poles and winds) 3. Speed vs. shape of air masses 4. Weather fronts Demonstrations: Make a mercury barometer and compare with an aneroid barometer. Use a topographic map to find your area's height above sea level. Calculate your psi. Cut out weather maps from the newspaper and note the lines that represent isobars and isotherms. Compare these maps and make weather predictions.
Given lists of relative humidities, air temperatures and weather conditions, the student will predict relationships and record them inchart form.	There is space between air molecules.	Lecture, demonstrations and student activities on relative humidity and (using a sling psychrometer to record relative humidity) temperature and weather conditions several days in a row.

Student Outcomes:	**Major Area Of Instruction:**	**Suggested Activities:**
Student will compare the difficulty of blowing up a balloon inside and outside a bottle and explain that difference in terms of air pressure.	Air takes the shape of the container in which it rests. ✍✍Air exerts pressure. ✍✍Confined gas will transmit pressure regardless of how it is generated (Pascal's law) ✍✍Solids transfer pressure in the direction of the force applied. ✍✍Fluids (including gases) transmit pressure in all directions.	Demonstration or student activities: 1. Blow up different shaped balloons. 2. Perhaps make balloon animal to create interest. Student activity: 1. Have student inflate an easy to blow up balloon. 2. Put the balloon into an empty soft drink bottle stretching the neck of the balloon over the mouth of the bottle. 3. Have student attempt to blow up the balloon again. 4. Put holes in another bottle. Set up as in #3. Why can one blow up the balloon now?
The student will: 1. Identify where air pressure is being applied to this system. 2. Measure the length of each stream of water. 3. Make a conclusion about whether a gas acts more like a fluid or a solid when pressure is applied.		Demonstration or student activity: 1. Drill three holes into a three-pound coffee can on three sides at different heights. These holes should be fitted with the same size corks. 2. Fill the can with water. 3. Take out one cork at a time. (Notice that the three streams of water are the same length.)

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Student Outcomes:	**Major Area Of Instruction:**	**Suggested Activities:**
Given a series of situations, the student will be able to analyze each situation to determine: 1. If work is being done 2. If potential or kinetic energy is being demonstrated. 3. If potential energy is being converted into kinetic energy.	Air can be compressed. Air can be used to do work (displacement over distance). Compressed air contains potential energy which can be converted into kinetic energy.	Lecture and demonstration on air pressure and air compression. Use a bicycle pump to blow up an inner tube. 1. Show how pump works. 2. Discuss differences in pressure as you are blowing up the tube, when tube is full and when deflating the tube.
The student will research and present (in an organized manner) one current or past issue of pneumatics. 1. Work it is designed to do. 2. How it is designed to do the work. 3. What it replaced. 4. Advantages and disadvantages.	Compressed air has been used to do work since early in man's history and continues to have major applications in industry today.	Lecture and demonstration on: 1. Work a) Pushing a stationary wall b) Pushing a moving desk c) Carrying a book across a room 2. Potential and Kinetic Energy a) Fill a balloon with air b) Release balloon 3. The history of using compressed air to do work.
Culminating student activity: Balloon rocket contest (groups of four) 1. Use two students to hold a string the length of the room (taut). 2. Give a variety of balloons, masking tape and a straw (to attach the balloon to the string). 3. Design the fastest balloon rocket.	All pneumatic systems operate by applying a force over an area.	Lecture: (Compressed air from a pump ? switch or valve ? pneumatic cylinder [compressed air expands against a cylinder forcing a piston to move] ? linear motion). Demonstration on the operation of a blow gun.

Note: The remaining section of the pneumatics unit is based on materials provided in the teacher's guide prepared for use with the LEGO DACTA® Pneumatic Set. This guide provides a very well structured and organized approach to teaching a "hands-on-program" in pneumatics. Activity cards provide students not only with simple building projects demonstrating important pneumatics principles but also with opportunities to design and build models to solve real world problems with pneumatics devices. Situations are presented in ways that promote the student's critical thinking skills and that provide opportunities to explore possible solutions to technical problems while meeting specific performance criteria.

Student Outcomes:	**Major Area Of Instruction:**	**Suggested Activities:**
The student will connect and operate a pneumatic pump, switch and cylinder.	Practice connecting and constructing using the LEGO DACTA® Pneumatics set.	LEGO DACTA® Pneumatic Activity #2 "Making Connections" (Green) Activity #1 “Simple Lift” (Blue)
The student will follow instructions to construct a simple pneumatic system. The student will investigate and record the advantages and disadvantages of a given pneumatic device.	There are advantages and disadvantages to the use of pneumatic systems.	Lecture and discussion: Advantages: 1. Air is available in an unlimited supply. 2. Compressed air can be stored and moved through pipes and hoses. 3. Air is a non-polluting and renewable resource. 4. Pneumatic devices are compact, lightweight and simple to construct. 5. These devices don’t overheat or spark and are easily adjustable. 6. High operating speeds can be generated. Disadvantages: 1. The energy required to compress air is expensive. 2. Compressed air must be kept clean and moisture free. 3.Pneumatic devices cause noise and can spray lubricating oil. 4. Pneumatic devices are limited in the force they can produce.

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Student Outcomes:	**Major Area Of Instruction:**	**Suggested Activities:**
Student will design and build a rescue device used to force open jammed doors of an automobile. Yellow Activity #5 "Jaws of Life"	There are many industrial applications for pneumatic devices: 1. Compressed air can be used to exert large forces. 2. Compressed air can be used to control more than motion at a time. 3. Compressed air can be used to control devices remotely.	Visit industrial facilities using pneumatics. Student activities: 1. (Blue) Activity #2 "Vertical Press" 2. (Yellow) Activity #2 "Back Saver" 3. (Red) Activity #2 Crushing Problem" 4. (Blue) Activity #5 "Dentist Chair"
Student will design and build a window opener that will be operated remotely (Yellow) Activity #1 "Wide Open"		(Red) Activity #1 "Drink Up"
Student will: 1. Design and build a gripper arm to grip and lift small objects of various sizes using pneumatic devices and levers. 2. Name each class of lever used in their device. 3. Find the mechanical advantage for each lever	Pneumatic systems are limited by the distance the piston can move. The direction and distance of movement can be changed by connecting levers or a series of levers to a pneumatic system. Levers attached to a pneumatic system can also change its mechanical advantages.	Lectures, problems and demonstrations on: 1. First, second and third class levers 2. Finding the mechanical advantage of each class of lever. Student activities: (Green) Activity #2 "Clever Lever" (Blue) Activity #3 "Scissors Lift" (Yellow) Activity #3 "Patient Pick-Up"
Student will design, build and record the processes involved in producing a finished product that executes a chosen task.	A scientific approach can be used to solve technical problems involving pneumatics.	“Loading Up” “Stamp-o-matic” “Big Ben” “Dino Motion”