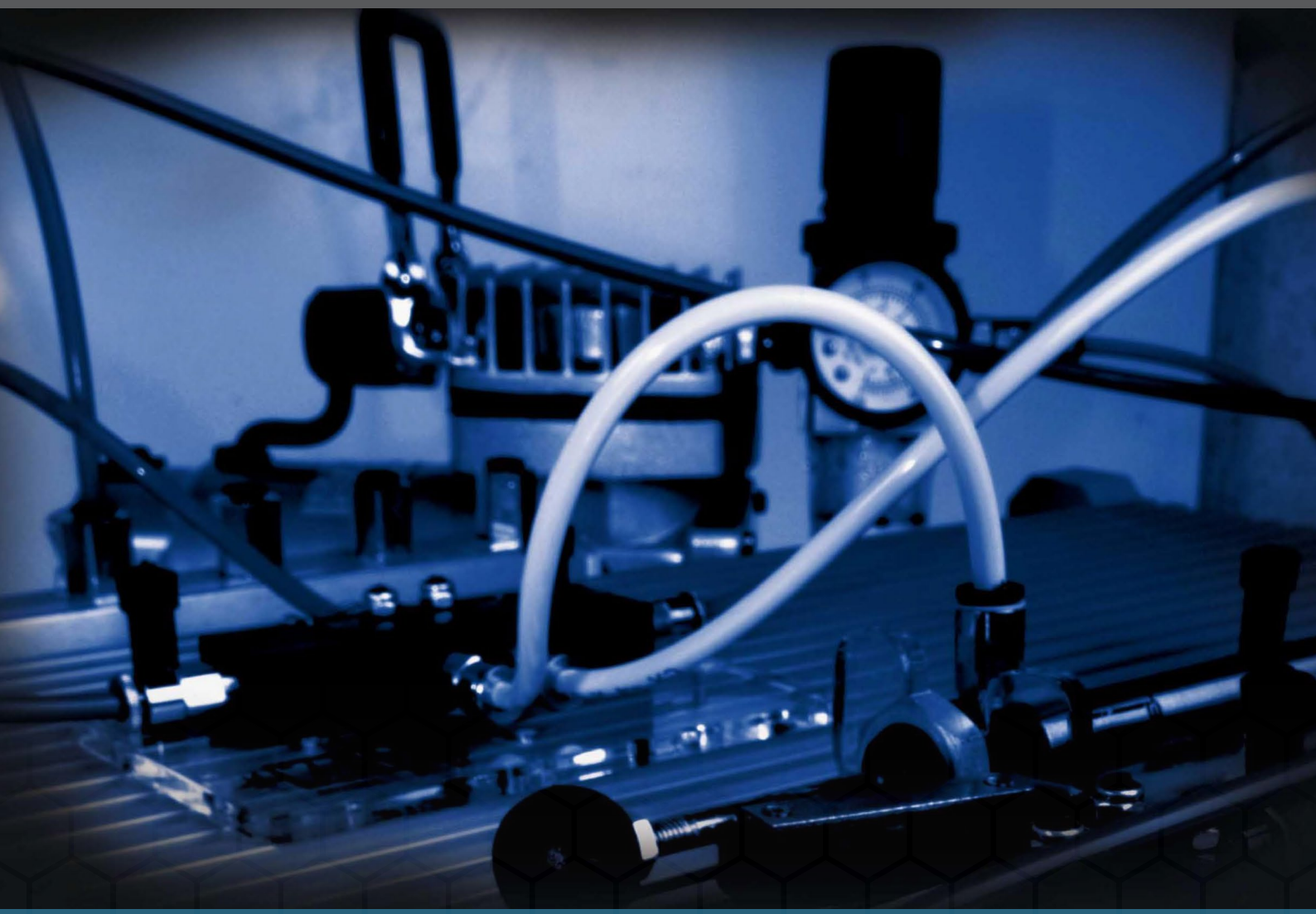
MATRIX | PNEUMATICS



PNEUMATICS ESSENTIALS

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Introduction

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WORKSHEETS

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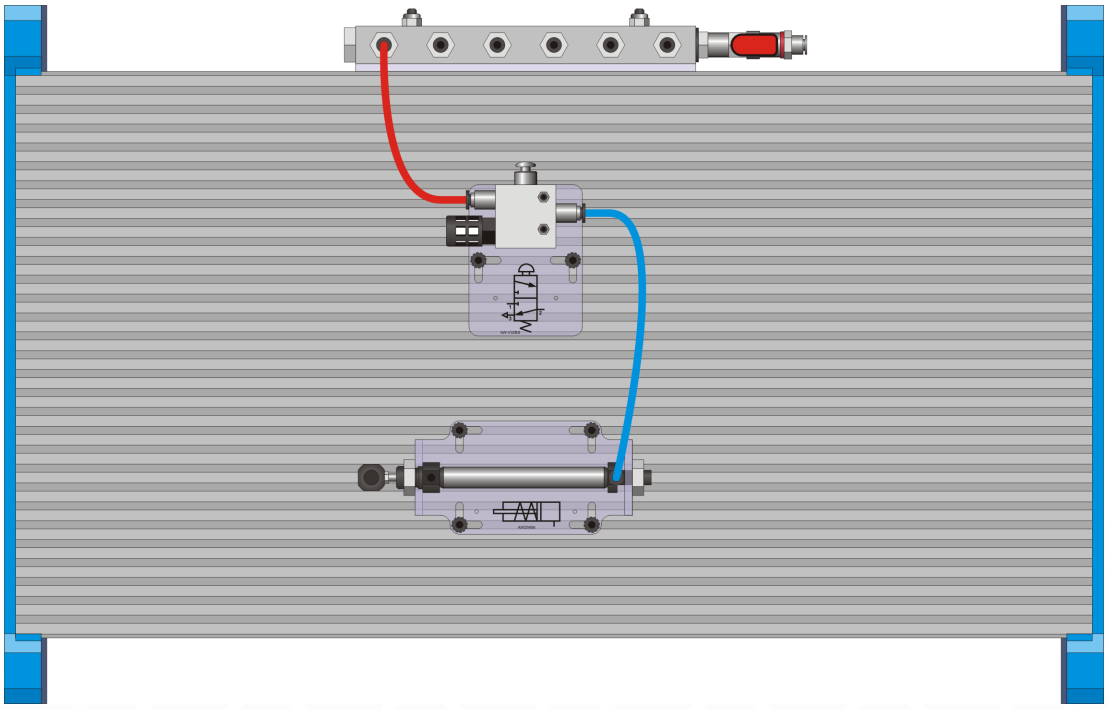
Safety Rules for Pneumatic Systems

Remember: compressed air and its components are capable of exerting large forces.

1. Never blow compressed air at anyone.
2. Don't turn on the air supply until the circuit is complete.
3. If you find an air leak, turn off the air supply at once.
4. Always turn off the air supply before you alter a circuit.
5. Keep fingers clear of moving parts such as piston rods.
6. Wear safety spectacles when building and operating pneumatic circuits.

Over to You

- The red lever on the manifold must be turned off at this stage.
- Build the arrangement shown below. It contains a single-acting cylinder, the one with only one port, connected to a push-button 3-port valve, then through one port of the manifold to the compressor.
- Turn on the air supply.
- Press the button on the valve and keep it pressed. What happens?
- Now release the button. What happens?
- Try it again. Can you work out how the system operates?



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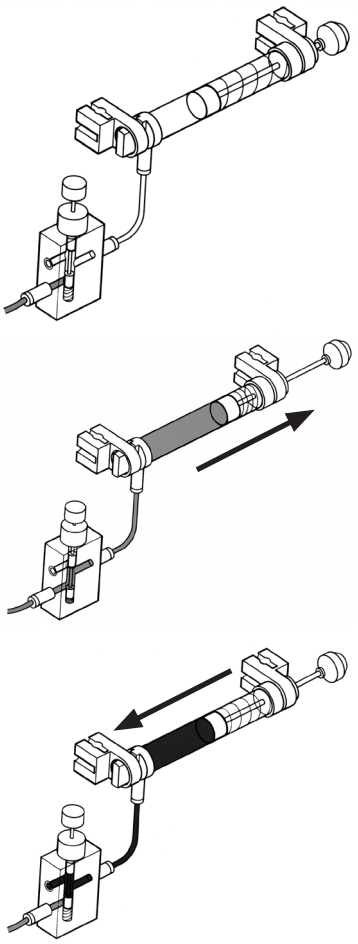
WORKSHEETS

Worksheet 1 – Safety First and Last

So What:

- The top diagram shows the valve in its unactuated state. The button is not pressed, and the valve stops air flowing from the manifold into the cylinder. The cylinder is retracted.
-
- When the button is pressed, the valve goes into its actuated state, and lets air flow into the cylinder. This pushes out the piston rod. The cylinder is now extended, as shown in the second diagram.
-
- When the button is released, the spring inside the valve pushes the disc back into the unactuated position. This allows air to flow from the cylinder, through the valve into the atmosphere. The cylinder spring can now push the piston back into the retracted position. You can hear and feel air coming out of valve port 3 as the cylinder retracts. This is called exhausting air and so port 3 is called the exhaust port.



Pneumatics vs Hydraulics:

- Fluid pressure in pneumatic control systems is ~ 10 times smaller than in hydraulic systems. As a result, pneumatic pistons must be ~ 10 times bigger in area to produce the same force.
- Hydraulic systems rely on the fact that liquids (the operating fluid) are incompressible.
- The working fluid in pneumatic systems (air) is very compressible. However, air is free, and is usually returned to the atmosphere. Hydraulic fluid is expensive, polluting and can be a health hazard. Leaks must be avoided at all costs.
- In pneumatic systems, air is compressed to the required pressure, but in the process it gets hot. In cooling it ready for use, some of the water vapour in it is deposited as condensation.
- In hydraulic systems, incompressibility means that speed can be controlled effectively by regulating the flow of the fluid to the cylinder, so that precise position control is achievable.

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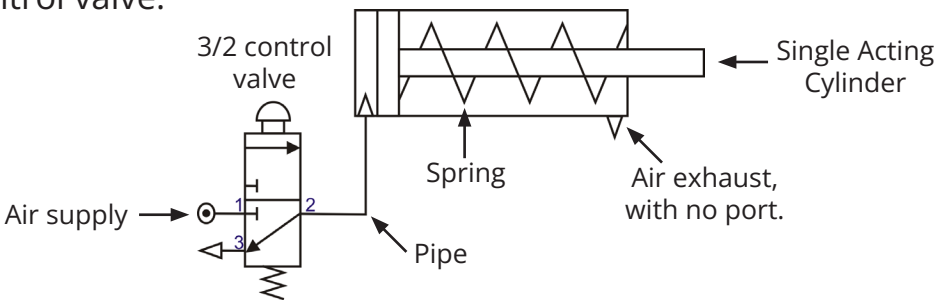
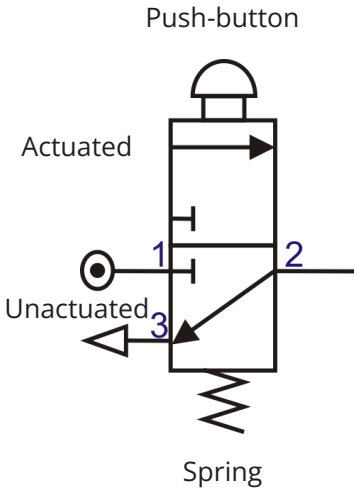
So What:

Symbols:
You just used a 'picture' of the system to build the circuit. However, to describe the system to someone else, it is usually drawn as a conventional circuit diagram, using standard symbols for the components, rather like a circuit diagram in electricity.
Here is the pneumatic circuit diagram for the system you just built, using the push-button 3/2 control valve:



The control valve is described as a **3/2** valve because it has **3** ports and **2** states.
The ports are numbered **1** to **3** on the diagram, alongside one of the states.
The two states are actuated, when the push-button is pressed, and
unactuated, when it is released and the spring takes over.



Each state is shown as a box. The valve has two states and so the symbol has two boxes.

One is attached to the push-button, and shows the effect of pushing it in. Here, air flows from the manifold (via port **1**) to the cylinder (via port **2**). The exhaust port (**3**) is blocked.

The other box, attached to the spring, shows what happens when the spring returns the valve to its unactuated state. Now, air from the manifold is blocked, (port 1) and instead, the cylinder is connected (via port **2**) to the exhaust port (**3**).

For your records:

- A control valve is described as a '5/3 spool' valve. Write a short (less than 25 words) description of this valve, covering all of the terms in italics.
- Using research on the internet or equivalent, create a table listing the relative advantages of pneumatic control systems and hydraulic control systems.
- Which type of control system would you use in:
  - a food factory;
  - earth-moving equipment?
- Give reasons for your choices.

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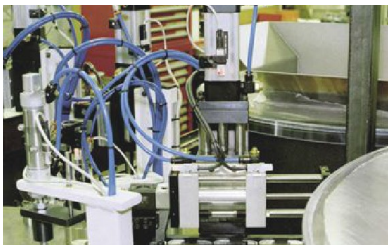
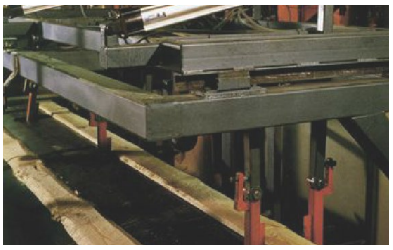
WORKSHEETS

Worksheet 2 – Control the Flow

There are three basic types of control system, electrical, hydraulic and pneumatic. There isn't a best or a worst. It all depends on the application.
Electrical control - for accuracy of movement or continuous motion, such as CNC machining, and in lift and locate assembly applications.
Hydraulics - for heavy loads, up to many tonnes, with immediate response or where full speed has to be achieved quickly.
Pneumatics - speed and force are controllable over a wide range. Pneumatic control systems function reliably under adverse conditions such as high and low temperatures, dirt, vibration, moisture, and electrical noise, and are intrinsically safe and non-contaminating, in, for example, food processing areas or when there is a risk of fire or explosion. They are tolerant to overloads and stalling.



Pressing cheeses



Manipulating timber planks

Move and clamp operation in automatic assembly

Over to You

- Once again, the red lever on the manifold must be off at this stage.
- Build the arrangement shown on the next page.
  - It is the one built previously, with a flow control valve added. The arrow on the underside of the valve points towards the cylinder.
- Turn the screw on the flow control valve right down.
- Turn on the air supply.
- Push the button on the three port valve. The piston rod should move very slowly or not at all.
- Now withdraw the screw as far as it will go and push the button again.
  - The piston rod moves much faster.
- Adjust the screw to give a moderate speed for the piston.
- Turn the red lever to switch off the air supply.
- Disconnect the flow control valve and re-connect it the other way round, (with the arrow pointing away from the cylinder.)
- Turn on the air supply, and press the button on the three port valve. Notice the difference.

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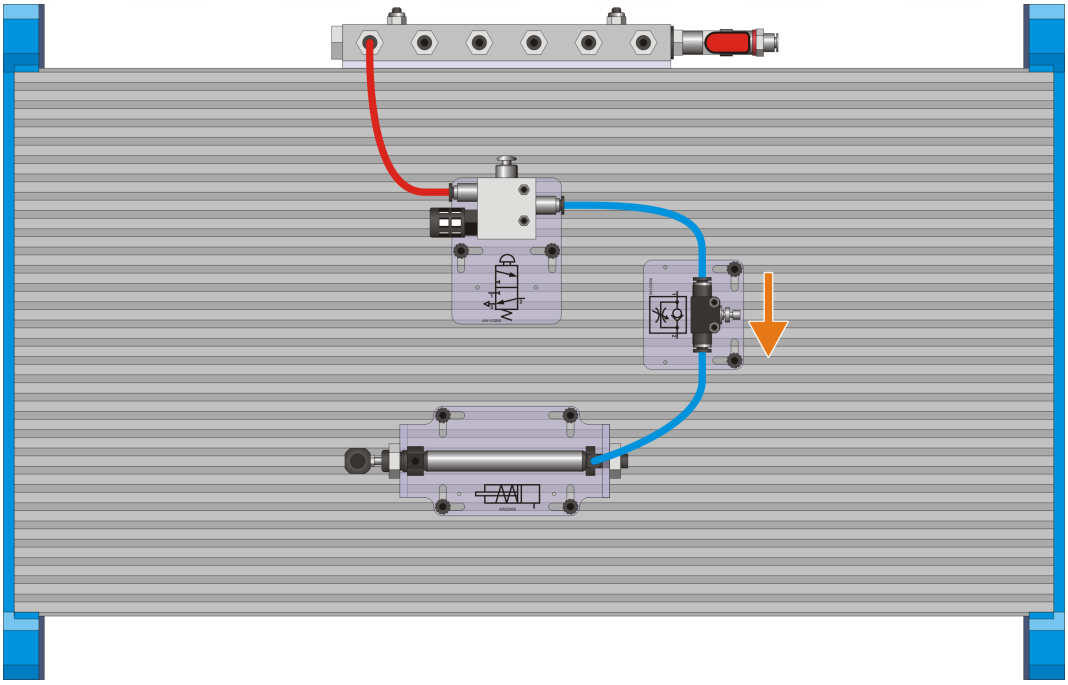
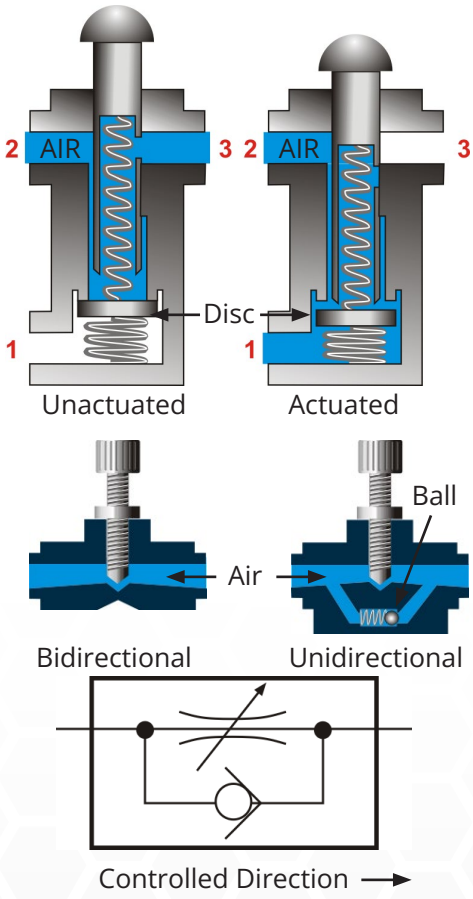
System for worksheet 2:



So What:

- The diagram opposite shows the action of the 3/2 control valve.
- The exhaust port of a pneumatic valve is often fitted with a silencer, to reduce noise and prevent contaminating the port. The symbol for this is shown below:

- Flow control valves can be either bidirectional, to reduce air flow in both directions, or unidirectional. In unidirectional valves, an arrow on the base of the valve shows the direction of the controlled air route. In the one shown opposite, controlled flow is from left to right. Here, air pushes the ball against its seat, blocking the by-pass channel. Air must flow down the main restricted channel. When air flows the other way, it pushes the ball away from the seat, allowing full flow down the by-pass channel.
- The symbol for a flow-control valve is shown opposite:



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WORKSHEETS

Worksheet 2 – Control the Flow

So What:

Next, some definitions, and the units used to measure them:

Mass (m) - measures how much matter (number of fundamental particles) in a body.

Force (F) - measured in kilograms (kg).
- a push or pull that causes motion, or stops it, or holds something in position.

Weight (W) - measured in units called newtons (N).
- the force which gravity exerts on a body.

Pressure (P) - also measured in newtons.
- measured in pascals (Pa), (1 Pa is a force of 1 N acting on an area of 1 m2.)

- These quantities are connected by the following equations:

W = m x g

F = P x A (or P = F / A or A = F / P)

where **g** is the gravitational field strength, usually taken as 10 N / kg.

The atmosphere we live in is about 8 km deep. Although we are not usually aware of it, this air has a considerable weight. As a result, it exerts an enormous pressure on everything it touches. Normal air pressure is taken to be roughly 100 kPa, or a force of 100 000 N pressing on every square metre of the surface of a body, though it varies with altitude and air temperature.

Sample calculations:

1. What is the weight of a 2.5 kg object?

Answer - Using **W = m x g**, the weight is 2.5 x 10 = 25 N.

2. What pressure is exerted on the floor by a person weighing 850 N and having a combined foot area of 0.05 m2?

Answer - Using **P = F / A**, the pressure is 850 / 0.05 = 17000 Pa (also written as 17 kPa.)

3. What force is exerted on a piston of area 0.001 m2 subjected to an air pressure of 500 kPa?

Answer - Using **F = P x A**, the force is 500 000 x 0.001 = 500 N.

For your records:

- Draw and label the symbols for the following pneumatic components:
  - single-acting cylinder
  - 3/2 push-button control valve
  - silencer
  - flow-control valve (showing the controlled direction.)
- Draw the pneumatic circuit diagram for the system you set up earlier in this worksheet.

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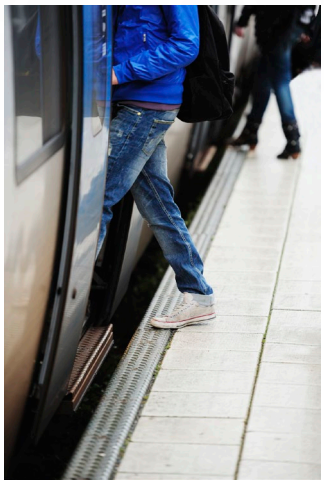
WORKSHEETS

Worksheet 3 – Automatic Door

A common use of pneumatics is in automatic doors, in buildings and vehicles.

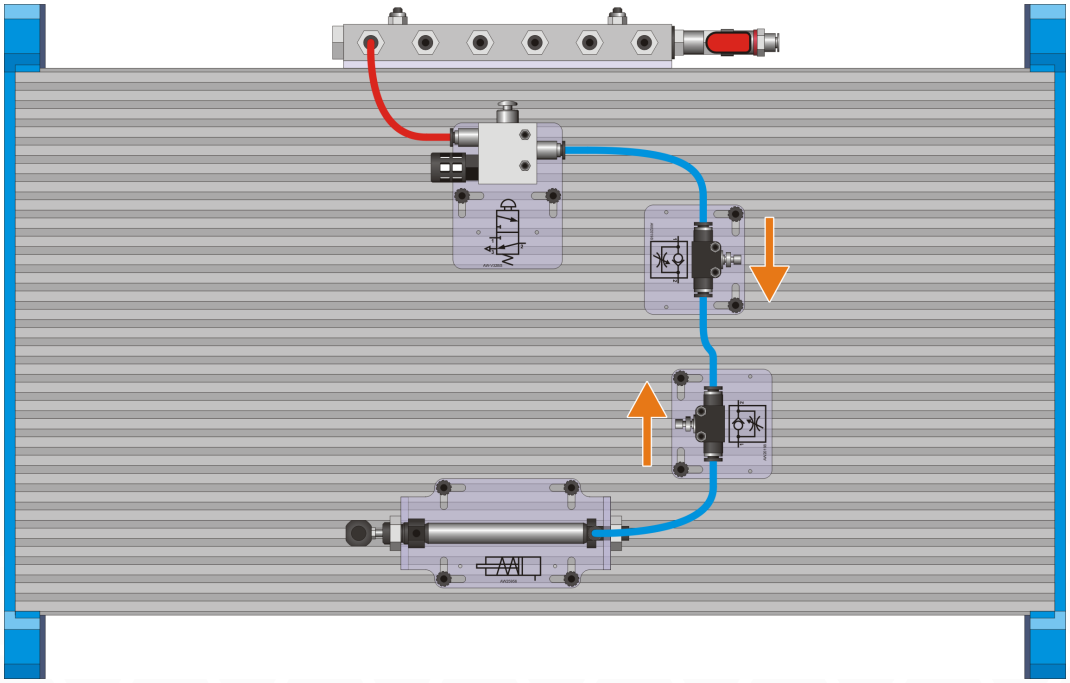


The control system must ensure that the door opens and closes at an appropriate speed - too fast, and it might injure someone or damage the hardware - too slow, and it delays people entering and leaving.

In the last worksheet, you used a unidirectional flow control valve to adjust the speed of a single-acting cylinder. Here, that system is extended to control speed in both extending and retracting, and a safety device and second switch are added.

Over to You

- As before, the red lever on the manifold must be off whenever you modify the system.
- Build the arrangement shown below - the one you just built, with another flow control valve added. The arrow on this second one points away from the cylinder.
- Adjust the screw on the second valve to match the first one.
- Turn on the air supply.
- Push the button on the 3-port valve. You should find that the piston now both extends and retracts at moderate speed. This could be connected to the door mechanism, and operate the door automatically when a button is pressed.



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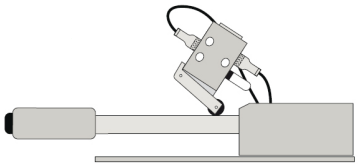
WORKSHEETS

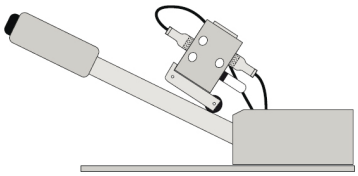
Worksheet 3 – Automatic Door

Over to You:

- Turn the red lever to switch off the air supply.
- Now add a safety device, to make sure that the door cannot be opened if the vehicle is still moving. This takes the form of a second control valve, operated by the vehicle brake. This valve is operated by a roller, as shown in the diagram.

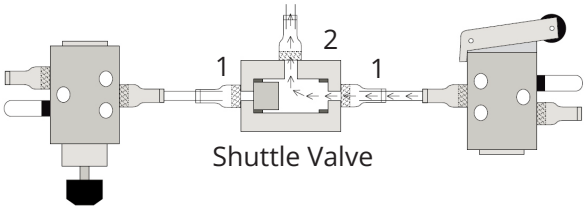


Brake off - valve unactuated



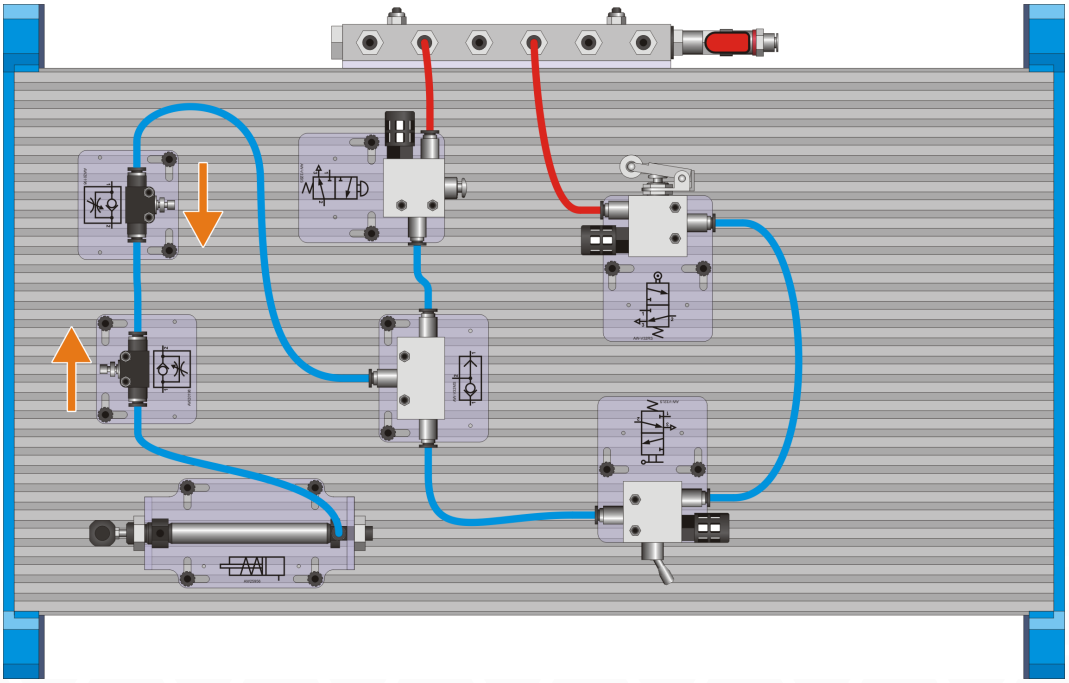
Brake on - valve actuated

- Next, add a second switch, so that the door can be opened from inside or outside the vehicle. This requires a new form of control valve called a shuttle valve, which allows two sources of compressed air to operate independently.



Shuttle Valve

- The full system is shown below.
- Turn on the air supply. Test the system to see if it performs as required.



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So What:

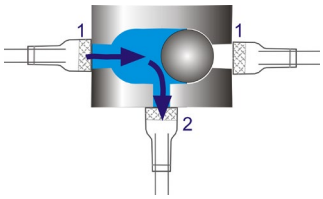
Types of actuators:
Control valves can be operated by a wide range of different actuators, including:

- lever switches;
- springs;
- foot pedals;
- rollers.

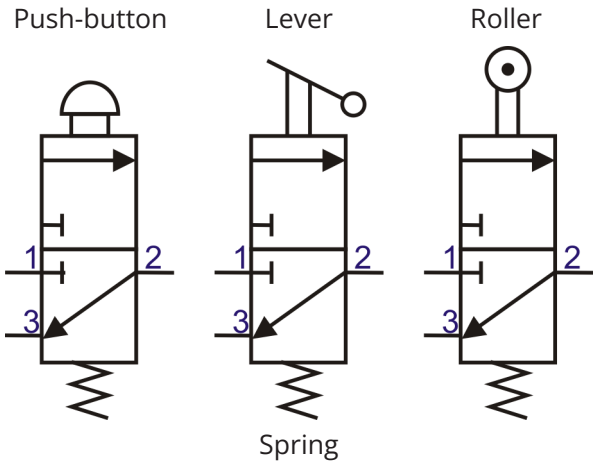
The symbols for a number of actuators are shown below. The symbol is attached to the end of the valve symbol.

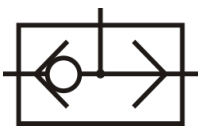
The shuttle valve:

- consists of a ball inside a cylinder. Air pressure applied to the left-hand port 1, blows the ball to the right, blocking the other port 1, and allowing air to flow out of port 2. When air pressure is applied to the other port 1, the ball is blown to the left, and air from the second source is flows out of port 2.
- equivalent to an 'OR-gate' in electronics;
- also known as the double-check valve.



Symbols




Shuttle Valve

For your records:

An object of mass m sits on the floor of a building. Its area of contact with the floor is A. It exerts a pressure P on the floor, because of its weight W, (the force pressing down on the floor.)
Copy and complete the following table, by using the formulae given earlier:

Mass of object m	Weight of object W	Area of contact A	Pressure exerted P
3kg		0.01m²	
	45N	0.001m²	
	2200N		11 kPa (= 11000 Pa)
10kg			150N

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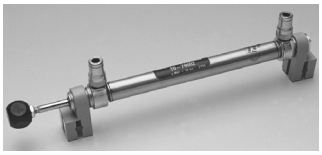
WORKSHEETS

Worksheet 4 – Push and Pull

Some jobs need the piston to push out to move an object. It can return under the action of the spring. That's when a single-acting cylinder is enough.
When you need to both push the piston out and force it back, both using compressed air, then a double-acting cylinder is needed.

Single-acting cylinder



Double-acting cylinder

What is the difference?

- Pull out the piston in a single-acting cylinder, and let go, and it flies back in, pushed by the spring. Doing the same with a double-acting cylinder leaves the piston extended.
- Single-acting cylinders have one port - double-acting have two.
- The return force in a single-acting cylinder is fixed - the force of the compressed spring. It may not be big enough to do the job! A double-acting cylinder usually exerts a much bigger return force.

In a car factory, metal parts are dipped in solvent to remove grease. Could a single acting cylinder raise and lower the basket?
More than likely, the spring wouldn't be strong enough to raise the heavy basket of components after they had been dipped.
The best type of cylinder to use for this job is a double acting cylinder, which uses compressed air to extend the piston and also to retract it.

Over to You

- As before, the red lever on the manifold must be off whenever you modify the system.
- Build the arrangement shown on the next page, using a double-acting cylinder.
- It uses two 3/2 control valves - one to extend the cylinder and the other to retract it.
- Turn on the air supply.
- Press the push-button to extend the cylinder. Notice that nothing happens when you release the valve.
- Next, press the roller on top of the second valve. As air pushes the piston back, air from in front of the piston exhausts from the push-button valve.
- What do you think will happen if you actuate both valves at the same time? Try it!
- Now leave both valves unpressed and try moving the piston. It moves easily because air from either side of the piston can exhaust freely from the unactuated valves.

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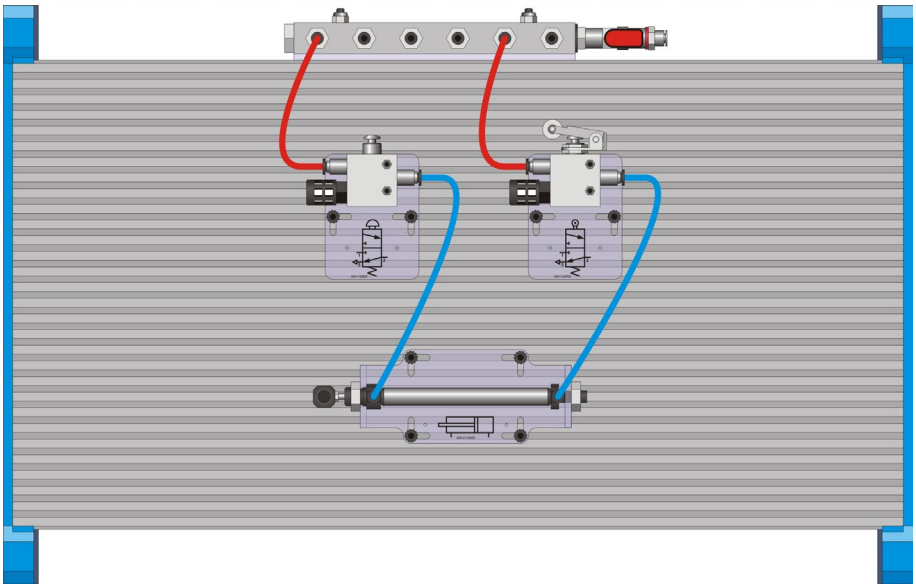
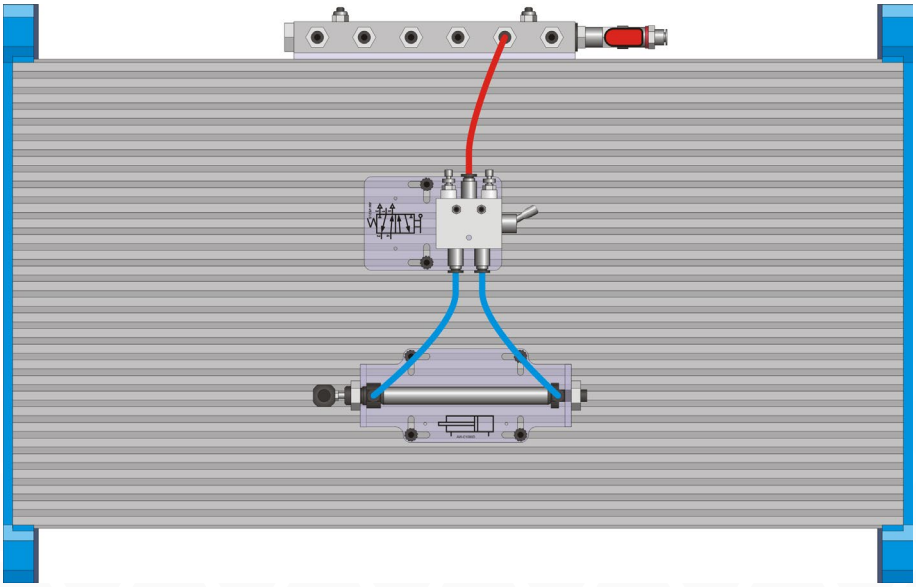
Layout for worksheet 4:



- Turn the red lever to switch off the air supply.
- A better way to control the double-acting cylinder is to use a five port valve. Build the circuit shown below, which uses a 5/2 lever operated control valve.
- Turn on the air supply.
- Operate the lever on the five port valve, to check that it can both extend and retract the piston. Can you move the piston rod by hand now?
- The piston rod might move too quickly for the application in hand. You could add flow control valves, but it is simpler to use exhaust restrictors, which screw into the exhaust ports of the control valve. Adjust the screw so that the basket is lowered steadily into the solvent. Then adjust the other exhaust restrictor so that the basket is lifted out at a suitable speed.



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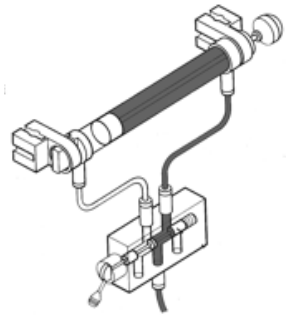
WORKSHEETS

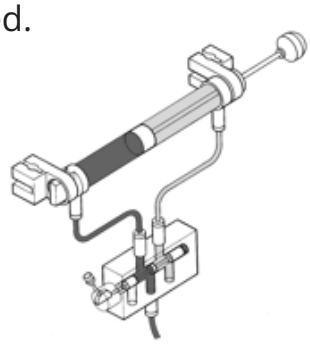
Worksheet 4 – Push and Pull

So What:

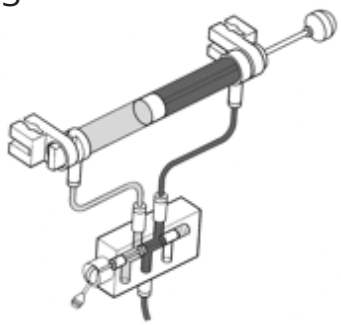
Five port valve:
The improved system for dipping the car components uses a lever operated five port valve, sometimes called a 5/2 valve because it has five ports and two possible states. The one shown here is not fitted with exhaust restrictors.



In the first diagram, the spool allows air to flow from the manifold into the front of the cylinder which keeps it retracted.

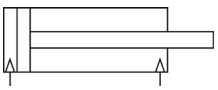


Here, air flows from the manifold into the cylinder to extend it. Air in front of the piston can exhaust through port 3

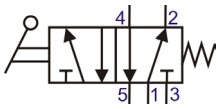


When the valve spring pushes the spool back, air flows from the manifold into the front of the cylinder to retract it. Air behind the piston can exhaust through port 5.

Symbols



Double-acting cylinder



Lever operated 5/2 control valve

Exhaust restrictor

For your records:

- Draw and label the symbols for the following:
  - double-acting cylinder
  - 5/2 roller-operated control valve
  - shuttle valve
  - exhaust restrictor

- Draw the pneumatic circuit diagram for:
  - the final system you set up in worksheet 3
  - the final system you set up in worksheet 4

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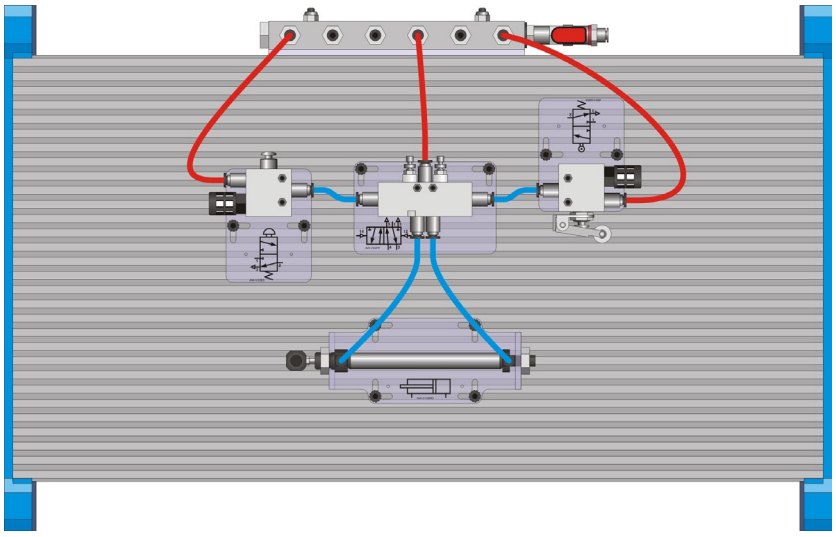
Some applications require considerable force to operate the control valves. Here, a two-stage process, using pilot-operated valves can be used.

In these, the large, main valve is operated by a smaller, low pressure, pilot valve. Usually, both valves are housed in the same unit.

Over to You

- As usual, the red lever on the manifold must be off whenever you modify the system.
- The Pneumatics essentials kit contains a five port valve, inside which the spool is moved from one position to another by compressed air. The two extra ports, one at either end, numbered 12 and 14, are called pilot ports. The valves that control the air to the pilot ports are called pilot valves.
- Build the arrangement shown below. It uses two 3/2 control valves, one push-button operated, one roller operated, as pilot valves.
- Turn on the air supply, and check that the system behaves in the same way as that in the last worksheet.



- By changing the layout of the components, the same system can make the cylinder retract automatically. The new layout is shown on the next page.
- Turn the red lever to switch off the air supply.
- Build the new system. Notice that the cylinder has been reversed. Bolt down the the roller operated valve firmly in a position where the fully extended piston rod just presses it down.
- Turn on the air supply, and check that the system behaves as required.

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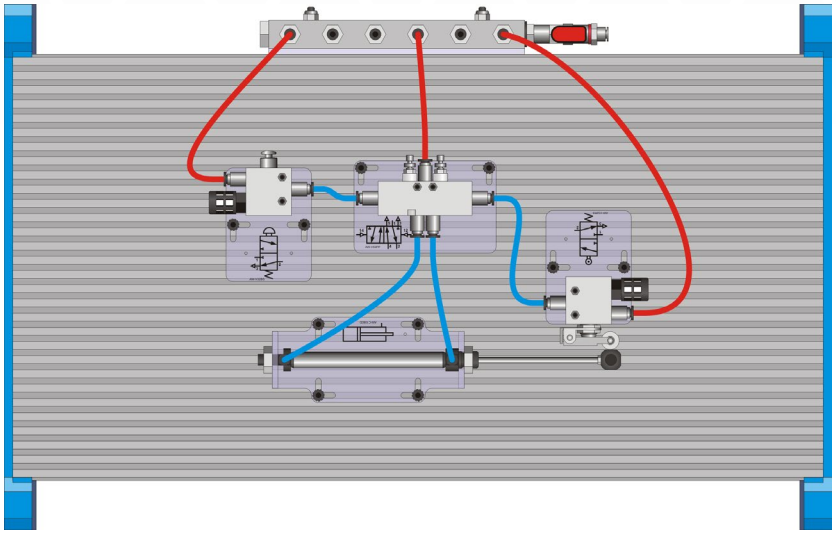
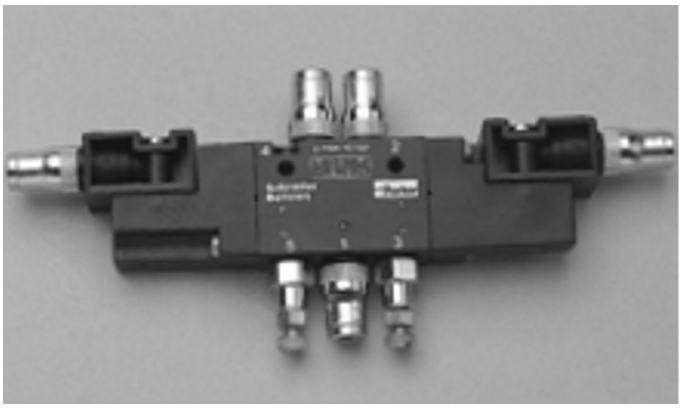
WORKSHEETS

Worksheet 5 – More for Less



- When the system works properly, adjust the exhaust restrictors on the 5/2 valve so that the cylinder extends quickly, but retracts slowly. A system like this could be used to operate an animated figure on a theme park ride. As the vehicle passes, it presses a button. The bandit pops up and then disappears again automatically.



5/2 pilot control valve

Pneumatically controlled animated bandit figure

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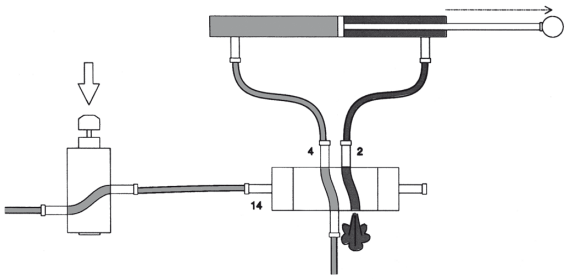
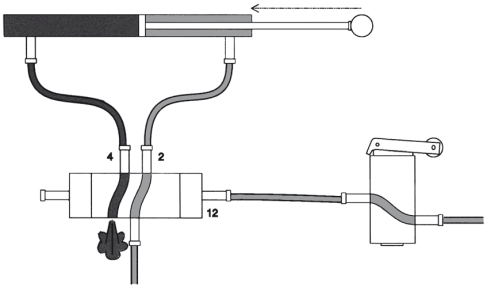
So What:

Pilot operated five port valve:
The Pneumatics essentials kit contains a type of five port valve that is not operated by a mechanical actuator such as a lever or a button.

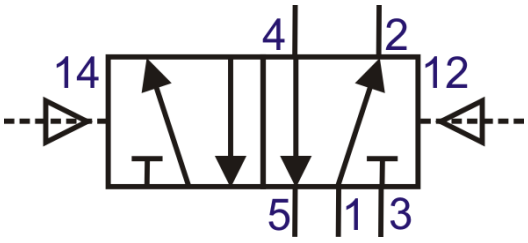


The spool inside the valve is moved from one position to another by compressed air. This is called a pilot/pilot five port valve. It has two extra ports, one at either end, called pilot ports and numbered 12 and 14. When air is sent to pilot port 14, the spool is moved to the position shown.

The spool moves into its other position when air is sent to pilot port 12.



Symbols
Pilot pressure lines are normally shown as dotted lines in circuit diagrams.



Pilot controlled 5/2 valve

For your records:

- Use the details given on this page, and the circuit symbol to describe the operation of the pilot 5/2 valve. Your description should cover all the port numbers given on the circuit symbol.
- Use the internet or equivalent resource to find an example of the use of pilot air controlled pneumatic valves. Explain why it is necessary to use pilot valves in your chosen application.
- Use the internet or equivalent resource to find an application where a pneumatic cylinder uses automatic retraction. Write a short description of the application.

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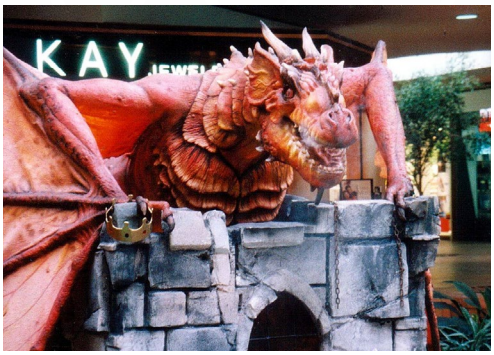
WORKSHEETS

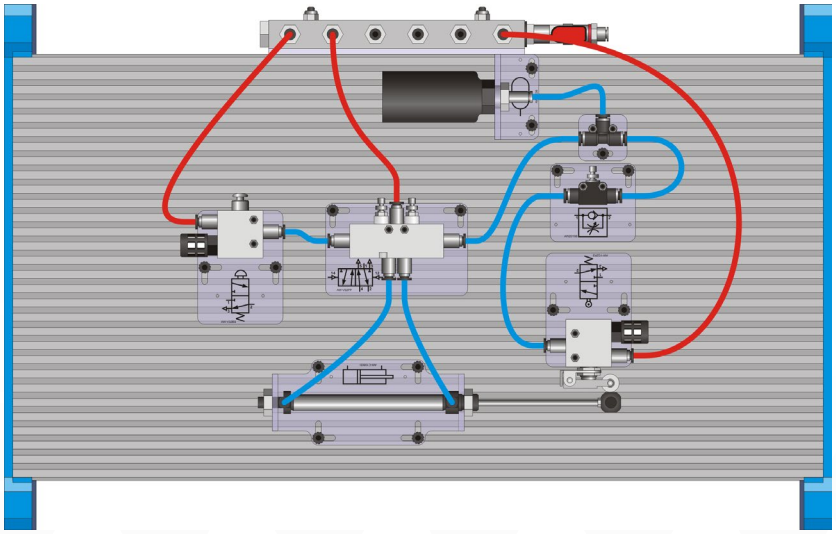
Worksheet 6 – Animated Additions

Theme parks thrive on animatronics figures, that move, breathe fire, roar etc. Our bandit in the last worksheet seems tame by comparison. It leapt up, and sank back slowly.
In this worksheet, we look at two techniques that could improve the performance. One adds a time delay, and the other uses a less intrusive form of triggering, related to the pilot air triggering we saw earlier.



Over to You

- Make sure that the red lever on the manifold is off whenever you modify the system.
- The first new device is an air reservoir, a container for compressed air. This is bolted to the platform with short T-bolts in the usual way.
- Build the circuit shown below. It uses a T-connector to create a branch for the reservoir, and a flow control valve, to control the rate at which air flows into the reservoir. The slower the air flow, the longer it takes for pressure to build up in the reservoir, and as a result, the greater the delay.
- Turn on the air supply.
- Screw the flow control valve out to its most open state, and operate the circuit. There will be only a very short delay before the cylinder retracts.
- Screw the flow control valve down completely, and then unscrew it slightly. This will give a much longer time delay.



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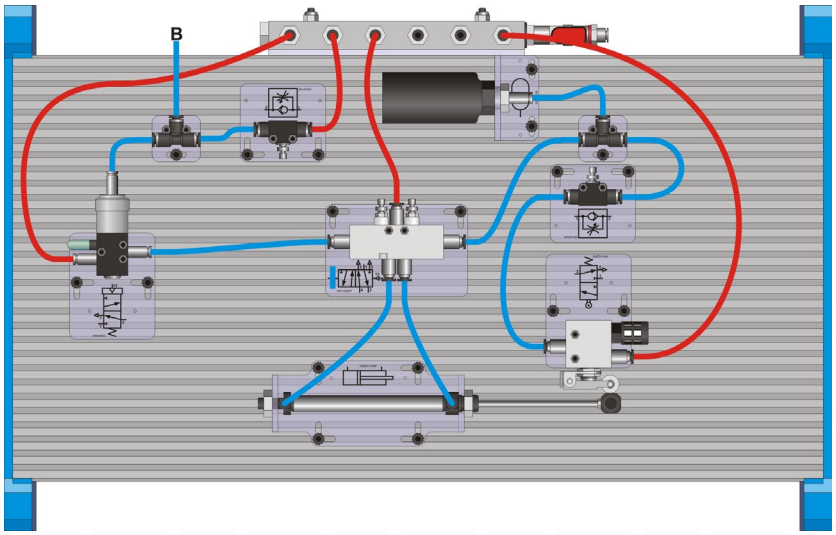
Over to You:

- Make sure that the red lever on the manifold is off whenever you modify the system.
- The second device is called a diaphragm valve, or pressure-sensitive valve. The one in the Pneumatics Essentials kit is a normal three port valve, but instead of having a mechanical actuator, it is actuated by a thin sheet of rubber called a diaphragm. This responds to an increase in the air pressure at port 12, the pilot port.
- Build the circuit shown below. This is called an air-bleed circuit, because air can escape slowly into the atmosphere. A flow control valve determines the rate at which the air bleeds out. Blocking the end of the bleed pipe, **B**, causes the pressure inside to increase. Eventually, this causes the diaphragm valve to actuate.
- Turn on the air supply.
- Test the circuit by blocking the end of the bleed pipe, **B**.
- **IMPORTANT**: Use the end of a pen or pencil to block the pipe. Don't use your finger.
- Remove the block as soon as the valve responds and extends the cylinder - don't allow too much pressure to build up on the diaphragm.
- How would the train trigger the valve as it passes the figure?
- Experiment with different settings of the flow control valve. If the air is allowed to bleed out quickly, pressure will build up sooner when the pipe is blocked. So, the diaphragm valve will respond more quickly.



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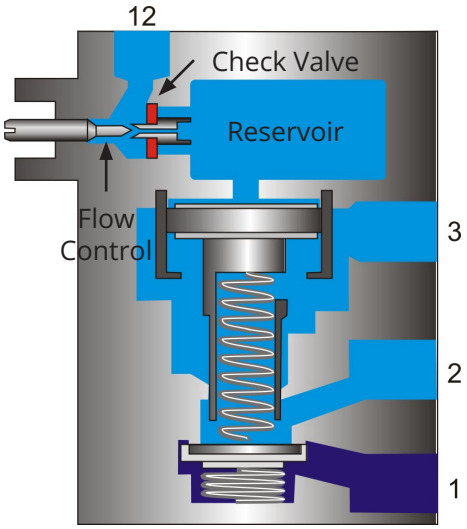
WORKSHEETS

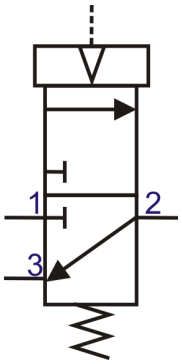
Worksheet 6 – Animated Additions

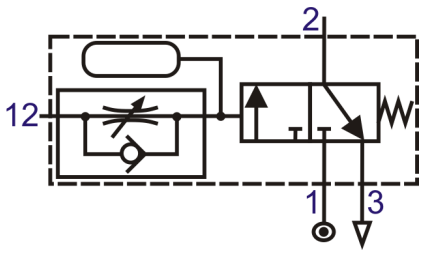
So What?

- Both circuits work in the same way: In the diaphragm valve, pressure builds up and eventually actuates the diaphragm valve.
- In the time delay circuit, the pressure inside the reservoir builds up slowly until it is high enough to trigger the valve.
- All three components of the time delay circuit, the reservoir, the flow control valve and the control valve itself are often incorporated into the one device, called a time delay valve.
- Time delay valves are operated by pilot air. The time taken for the air pressure to build is variable, set by adjusting the constriction in the flow control valve.
- Time delays are widely used in industrial equipment. For example, it may be used to give a tool time to clear the area before moving the work piece.



Symbols





Time Delay 3/2 Valve

For your records:

- Draw and label the symbols for the following:
  - pilot controlled 5/2 valve
  - air reservoir
  - diaphragm 3/2 valve
  - time delay 3/2 valve
- Draw the pneumatic circuit diagram for the first system you set up in worksheet 6.
- An automatic door opening system must:
  - be able to be opened from inside or outside by pushing a button;
  - remain open for an adjustable time period;
  - then close automatically;
  - have a means to keep the door open continuously when needed.
- Draw a pneumatic circuit diagram for this system.

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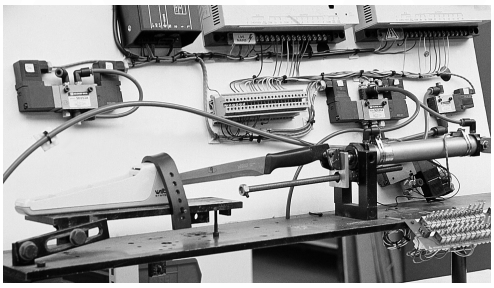
WORKSHEETS

Worksheet 7 – Reciprocation, Reciprocation, Reciprocation

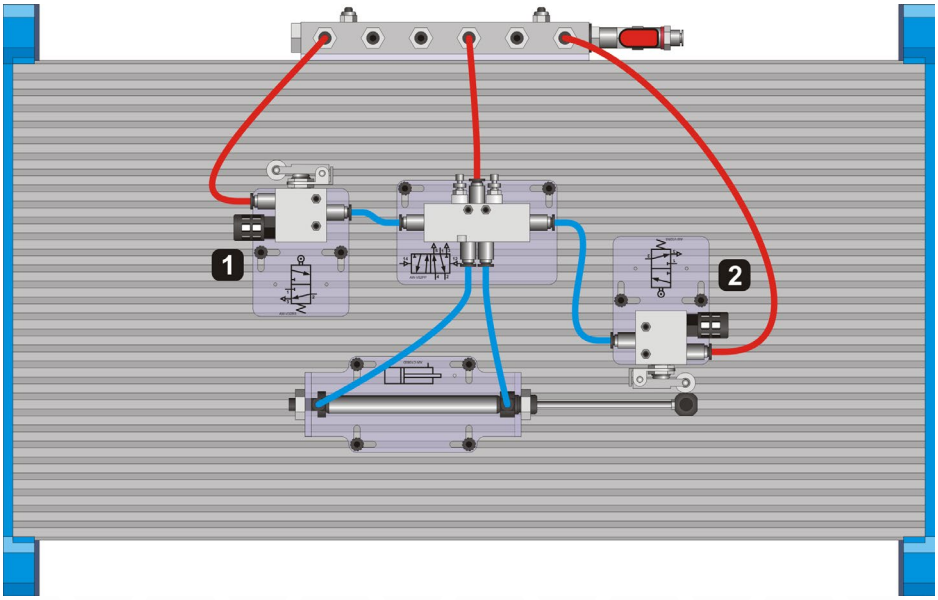


Consumer goods must be 'fit for purpose'. Whether it's a mattress, cupboard hinge or tennis racquet, the manufacturer must test it for performance and durability.
The picture shows a knife-testing rig. The knife is pushed in and out of the knife holder repeatedly to simulate a lifetime of normal use.

Pneumatic circuits offer a controlled way to conduct these endurance tests. What is needed is a system that reproduces the desired movement over and over again - reciprocating motion.
That is the focus of this worksheet.

Over to You

- Make sure that the red lever on the manifold is off whenever you modify the system.
- Begin by building the automatic return circuit shown below.
- Bolt valve 2 down securely, but don't bolt down valve 1 yet.
- Turn on the air supply.
- Test the circuit by operating the roller on valve 1.
- Make sure that the piston rod actuates roller valve 2 and returns properly.
- Adjust the exhaust restrictors so that the piston rod moves at a medium speed.



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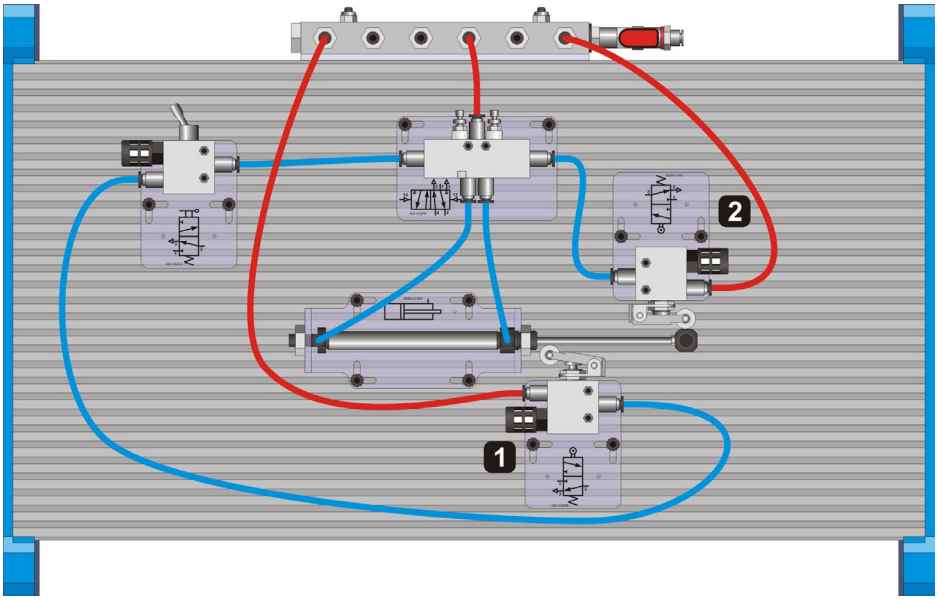
WORKSHEETS

Worksheet 7 – Reciprocation, Reciprocation, Reciprocation

Over to You:

- Make sure that the red lever on the manifold is off whenever you modify the system.
- Now, turn off the air supply and build the circuit shown below.
- Position valve 1 so that when the piston rod is fully retracted, it presses the roller down. Then bolt it down securely.
- Turn on the air supply and actuate the lever valve. The piston rod should continue to reciprocate until you stop it with the lever valve.
- Turn off the air supply.
- Now change the position of the lever valve so the circuit will stop with the cylinder extended.
- Turn on the air supply and test your new arrangement.



- If the circuit doesn't work properly, turn off the air supply and check that the two roller valves are securely bolted down in the correct position so that the ball on the piston rod presses the rollers down fully.
- Make sure that, as it extends, the piston rod doesn't keep the roller on valve 1 pressed down.

Don't try to operate or reposition the roller valves while the air supply is turned on.

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So What?

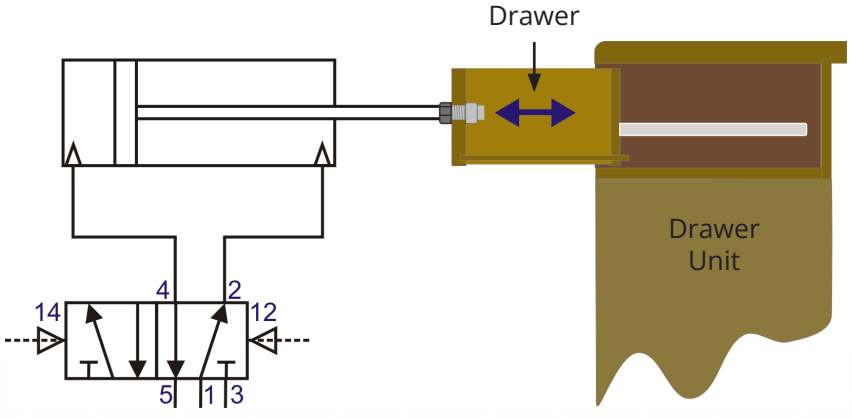
When the lever valve is closed in the pneumatic circuit shown on the previous page, the following sequence of events takes place:

- the cylinder is already retracted, and so valve 1 is actuated by the ball on the piston rod;
- air flows through valve 1 and the lever valve into the pilot 5/2 valve making the cylinder extend;
- as this happens, valve 1 is released;
- eventually, the piston rod actuates valve 2;
- air flows into the other pilot port of the pilot 5/2 valve, causing the cylinder to retract;
- as this happens, valve 2 is released;
- eventually, the ball on the piston rod actuates valve 1.

This process repeats until the lever valve is switched off. Then, the piston stops moving when the cylinder is retracted.

For your records:

- A furniture manufacturer uses a pneumatic test-rig to check for wear-and-tear on drawers in a new drawer unit. Part of the circuit is shown below. A reciprocating double-acting cylinder opens and closes the drawer repeatedly. However, it is found that the test-rig moves the drawers too rapidly. Suggest how it can be modified to operate more slowly. Copy the pneumatic circuit diagram and complete it to show your modification.



- Which is greater - the force exerted as the cylinder extends, or the force exerted as it retracts? Explain your reasoning.

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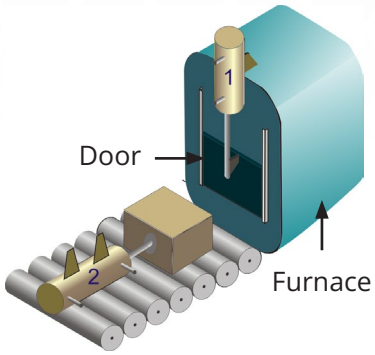
WORKSHEETS

Worksheet 8 – In Sequence

Often, two or more pneumatic cylinders work in collaboration.
In the case shown, one cylinder opens the furnace door, and then the other pushes the sample inside. The second cylinder retracts, and then the first one closes the door.
Such sequences can be carried out using only pneumatics, or by using electronics to control the pneumatics, as is shown in a later module.



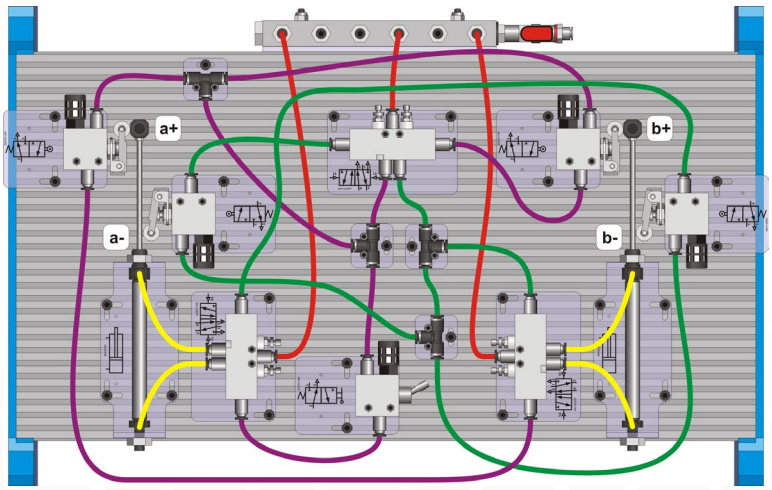
Over to You

The circuit for dipping car components, in Worksheet 4, is improved by using two cylinders in a sequence. The new system, shown here, means that the operator does not have to lean out over the tank.
The sequence is:

- Cylinder A extends to position the basket over the tank.
- Cylinder B extends to dip the basket.
- Cylinder B retracts to lift the basket out of the tank.
- Cylinder A retracts to bring the basket back to its starting position.

This sequence can be written as 'A+, B+, B-, A-'

- Make sure that the red lever on the manifold is off whenever you modify the system.
-
- Build the circuit shown below. Take care to check that all connections are made correctly.
- The colour code highlights the two air supply groups.
- Turn on the air supply.
- Test the system, and use it to work through the explanation given on the next page.



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Over to You:

The solution is an example of the cascade method for designing sequential control systems.
This divides the air supply to the pilot valves into two groups.
In the diagram on the next page, shown in purple, group I supplies the Start valve and valves a+ and b+.
Group II, shown in green, supplies valves a- and b-.
A pilot/pilot five port valve switches the air supply from one group to the other, half way through the sequence. This valve is called the group changeover valve.

How the Circuit Works:

1. Switching on the Start valve sends a signal to port **14** of control valve **a**, extending cylinder **A**.

2. Cylinder **A** piston rod then actuates valve **a+**, sending a signal to port **14** of control valve **b**. This extends cylinder **B**.

3. Changeover: The next step in the sequence is for cylinder **B** to retract. This requires a signal at port **12** of control valve **b**, but this valve is already receiving a conflicting signal at port **14** from pilot valve **a+**.
The air supply to pilot valve **a+** must therefore be removed before the sequence can continue. This is done by changing the air supply from group I to group II.
When cylinder **B** extends, the signal from pilot valve b+ goes to port 14 of the group changeover valve and this switches the air supply from group I to group II.

4. Following this changeover, a signal is immediately sent to port **12** of control valve b, which retracts cylinder **B**.

5. The signal from pilot valve **b-** goes to port **12** of control valve a to retract cylinder **A**.

6. Continue or Stop When cylinder **A** retracts, it actuates pilot valve a- and a signal is sent to the group changeover valve to switch the air supply back to group I.
As soon as the air supply is switched to group I, a signal is sent through the Start valve to control valve a to extend cylinder **A** again and so repeat the sequence. The sequence will continue to repeat itself as long as the Start valve is open.
Whenever it is closed, the sequence will stop after cylinder **A** retracts.
The component dipping system requires just one sequence at a time, so the operator would close the start valve before the sequence ends.

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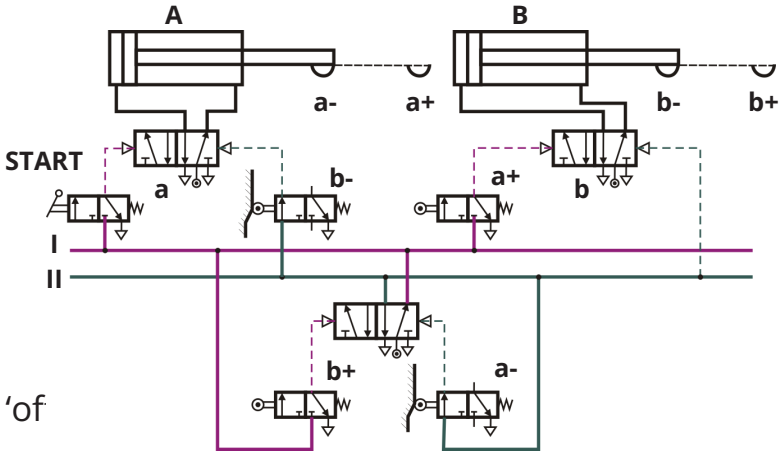
WORKSHEETS

Worksheet 8 – In Sequence

Over to You:

Cascade circuit diagrams would be difficult to follow if drawn like the one earlier, with pilot valves shown in their actual positions.

Instead, they are drawn in a 'virtual' simplified manner.
The one shown opposite is the A+, B+, B-, A- circuit.



The colour coding is the same as that used earlier.

The diagram shows the circuit in its 'of

Group I and II busbars are shown clearly. (A busbar shows all connections linking one port of the group changeover valve to the pilot lines.) Notice the way in which valves a- and b- are shown to be actuated.

Fault Finding

If your circuit doesn't work properly, follow this procedure:

- Turn off the air supply.
- Check that all pipes are pushed firmly into their fittings.
- Check that the roller valves are securely bolted down and correctly positioned.

The ball on the piston rod should press down the roller firmly when it hits it. The piston rod should also release the roller fully when it moves away.
You may need to adjust the exhaust restrictors on the control valves. The piston rods should move quickly enough to actuate the rollers, but not so quickly that they push the valves out of position.
Check all piping methodically.

- Work along each busbar, ticking off each correct connection.
- Turn on the air supply and test the circuit again.

For your records:

- Copy the cascade circuit diagram for the A+, B+, B-, A- sequence, and add an explanation of how the system generates the required sequence.
- Research and then describe an application that requires the sequence A+, A-, B+, B-.
- Draw the cascade circuit diagram for a system that produces the sequence A+, A-, B+, B-.

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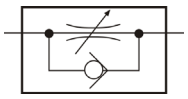
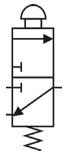
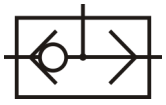
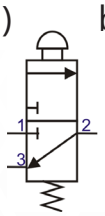
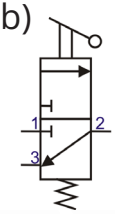
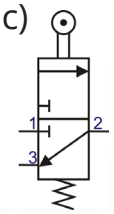
About These Questions

These questions are designed to be a useful aid to revision.
Allow 25 minutes to answer them and then check your answers with those given on page 32.
For each of the following, choose the correct answer (a, b or c).

1. What is the name of the machine that provides a supply of pressurised air?
a) condenser b) compressor c) contractor
2. Which type of movement does a pneumatic cylinder NOT provide?
a) linear b) reciprocating c) rotary
3. What should you do first if you notice air escaping from a pneumatic circuit?
a) tell somebody b) turn off the air supply c) panic
4. A single acting cylinder is extended by air. How is it retracted?
a) by a spring b) by air c) by gravity
5. Air flowing out of a cylinder as it retracts is called:
a) exhausting air b) retiring air c) wasted air
6. What is the name of the valve that varies the speed of a piston?
a) three port valve b) shuttle valve c) flow control valve
7. Lever, push button, roller are all types of:
a) valve actor b) valve actuator c) valve automator
8. Match up each of the valve names in List One to the symbols in List Two.

List One	List Two
a) 3 port control valve	1. 
b) Shuttle valve	2. 
c) Flow control valve	3. 

9. Which of the following is operated by a lever switch?

a)  b)  c) 

10. Which symbol shows that a port is connected to the pressurised air supply?

a)  b)  c) 

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REVISION

Revision Questions

11). A double acting cylinder is extended by air. How is it retracted?

a) by a spring b) by air c) by gravity

12. Which of the ports on a five port valve is connected to the air supply?

a) port 1 b) port 2 c) port 3

13. Which one of these ports on a five port valve would have an exhaust restrictor fitted to it?

a) port 2 b) port 3 c) port 4

14. An automatic return circuit uses:

a) by-pass valves b) shuttle valves c) pilot valves

15. What is the force in N exerted on a piston of area 0.01 m2 by air pressure of 150 000 N.m-2?

a) 6.7 x 10-8 b) 1 500 c) 15 000 000

16. When air is sent to port 14 of a five port pilot/pilot valve, air flows from port 1 to:

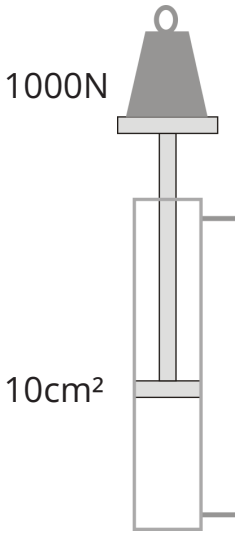
a) port 4 b) port 3 c) port 2

17. A diaphragm valve is actuated by:

a) a change in air pressure at port 1

b) a change in air pressure at port 12

c) a push-button

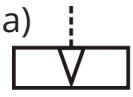


18). A vertical cylinder, with a piston area of 10cm2, is used to raise a load of 1 000N. When both ports are blocked, the load stops moving.

What is then the air pressure, in N.cm-2, inside the cylinder?

a) 0.01 b) 100 c) 10 000

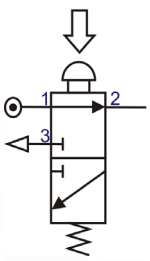
19. Which is the symbol for the actuator on a diaphragm valve?

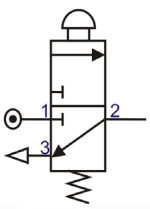
a) 

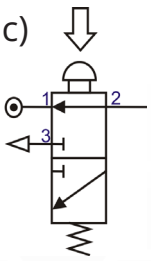
b) 

c) 

20. Which one of the following is the correct symbol for an **actuated** 3 port valve?

a) 

b) 

c) 

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For each scenario:

- design a pneumatic circuit that could be used to meet the client's requirements.
- make a drawing of the circuit.
- provide notes to explain to the client the purpose of each component you have used.

1. Stamping machine:

Remember that the boxes are fragile, and so the stamp should not hit them too hard.

Your design should include a safety guard around all moving parts, and be designed so that the machine cannot operate unless the guard is in place.

BURLINGTON
Hand Made Chocolates and Sweets

Dear Designer,

I own a small business which makes expensive, hand-made sweets and chocolates, which are packaged for sale, in cardboard boxes. Each box is individually printed with a price and a "sell-by" date, before it leaves the packaging department. The printing is done by hand, using a self-inking date stamp.

Our problem is that by the end of a shift, the people doing the date-stamping get very tired and bored. This means that the printing becomes very uneven, and the dates are sometimes up-side-down or in the wrong place on the box.

We need a stamping machine that will give us the same print every time – and won't get tired!

Can you please help.

2. Storeroom door:

The Cottage Loaf Bakery

Dear Designer,

Could you please help with a problem we are having with our store-room door?

It is very important that we keep the door of our store-room closed as much as possible so that our products are stored at an even temperature. However, the storekeeper has to go in with his arms full of boxes, which makes it difficult for him to open and close the door.

Can you design a pneumatic door-opener that will allow him to open the door by pressing a footswitch on the floor in front of the door. The door must close im-mediately he has gone through.

Obviously, we don't want the storekeeper to be trapped inside the store-room! So, he needs to be able to open the door either from inside or from out-side.

Yours sincerely,

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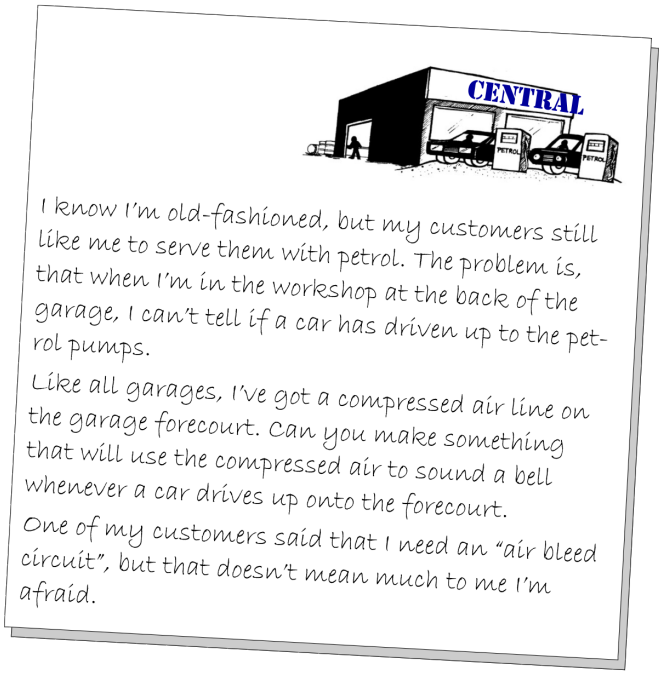
DESIGN SCENARIOS

Design Scenarios

For each scenario:

- design a pneumatic circuit that could be used to meet the client's requirements.
- make a drawing of the circuit.
- provide notes to explain to the client the purpose of each component you have used.

3. Forecourt alarm:



4. Product testing:

This scenario involves two different pneumatic circuits, *unless you can do it in one!*

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PNEUMATICS ESSENTIALS

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