Engineering Science

Pneumatics

Name ______________________________

Class ______________________________

Teacher ____________________________

Learning Intentions

- To know what Pneumatic Systems are and how they are used
- To know how to be safe when using pneumatics
- To know what cylinders are and how they are used
- To know what a valve is and how it is used
- To know how to create pneumatic circuits to complete every day tasks

Success Criteria

- I can identify 3 advantages and 3 disadvantages of using compressed air.
- I know what safety precautions to take when using compressed air.
- I can recognise and draw symbols used in pneumatic circuits.
- I can describe the function of several components used in pneumatic systems
- I can explain the terms in-stroke and out-stroke in relation to Pneumatic Control.
- I know how to create AND & OR control within a pneumatic circuit.
- I can create a circuit that works in a set sequence.
- I can create circuits that are manual and automatically controlled.
- I can create a time delays in pneumatics.
- I can do calculations using force, pressure and area.

To access video clips that go to

Pneumatic Systems

Pneumatics is something that you probably know very little about yet come across everyday without ever realising it. Some examples are shown below.



Pneumatics are used a lot in industry and you would expect to see pneumatics systems in factories, production lines and processing plants. It can be used to do lots of different jobs such as moving, holding or shaping objects.
Every one of these pneumatic systems makes use of compressed air.
In the classroom you are supplied with compressed air through a *manifold*. The manifold lets you connect lots of components to the compressed air.

Safety Rules

Safety rules help keep us safe. The highlight dangers and this helps to prevent accidents.
When we are using pneumatics we must follow these rules.

1. Never blow compressed air at anyone, not even yourself
2. Never let compressed air come into contact with your skin, as this can be very dangerous.
3. Always wear safety goggles when you are connecting and operating circuits.
4. Check that all airlines are connected before turning on the main air supply.
5. Always turn off the main air supply before changing circuit.
6. Keep you hands away from moving parts.
7. Avoid having airlines trailing across the floor or where someone could trip or become entangled.

Advantages of Pneumatic Systems

- Clean
  Pneumatic systems contain air, so a leak doesn't cause mess. Hydraulic systems contain oil, so leaks are messy, making them unsuitable for clean environments such as food factories.

- Safe
  Pneumatic systems don't produce sparks so there is no fire or explosion hazard. Compressed air, unlike oil or high voltage electricity, does not create any major environmental or accident hazard. Compared with electrical systems, pneumatic systems have an extremely high safety record. However they must still be treated responsibly. See the Safety section for more information.

- Dependable
  Pneumatic components are relatively simple and contain few moving parts. This means that they tend to last a long time and are generally easy to maintain. A pneumatic cylinder provides the simplest source of linear movement and force. It will operate continuously in a fast-cycling machine that is required to run 24 hours a day, seven days a week.

- Available
  The basic raw material is air which is available everywhere. Compressors can easily be made portable. Compressed air can be transported through piping over considerable distances, whereas each piece of hydraulic equipment in a factory generally needs its own power pack.

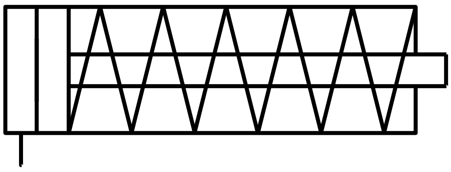
Disadvantages of Pneumatic Systems

- Small Forces
  Pneumatic components produce relatively small forces. Whenever large forces are required, hydraulic systems are used.
  Hydraulic systems contain liquid which, unlike air, cannot be compressed. This means they can create large forces, and that the force and speed of movement are more controllable.

- Not Energy Efficient
  Compared with an electrical system, a pneumatic system is not very energy-efficient.
  A lot of energy is converted in the production of compressed air at the input end of the system, compared with the amount of energy finally converted into movement at the output end of the system.

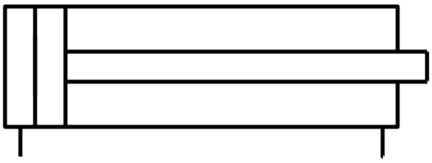
Components

Single-acting Cylinder, spring return



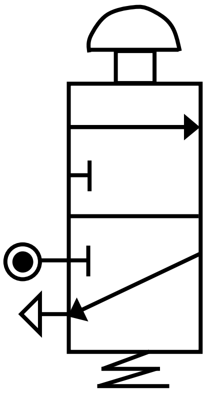
A Single-acting cylinder requires only one air supply. When air is put into the cylinder it outstrokes. After the cylinder has been de-activated it instrokes automatically, because of the spring.

Double-acting Cylinder



A double-acting cylinder has no spring inside to return it to its original position; *it needs two air supplies, one to outstroke and one to in stroke the piston.*

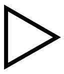
3/2 valves



This is a push button, spring return 3/2 valve.

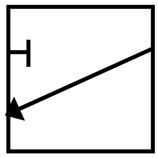
A 3/2 valve gets its name because it has 3 ports and 2 states.

A **port** is where we can connect a pipe;

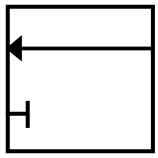
Port 1 – mains air – 
Port 2 – output connection –
Port 3 – exhaust air – 

A **state** is simply a position that the valve can be in;

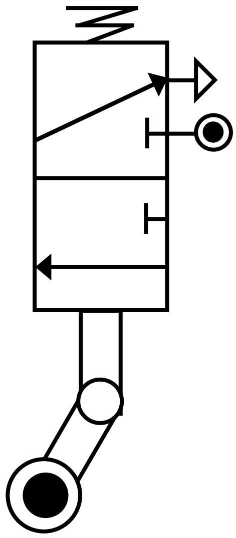
State 1 – off/actuated



State 2 – on/actuated

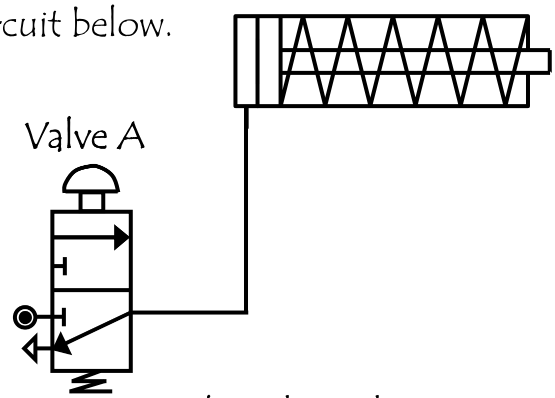


When naming the component you have to state its FULL name. For example this one would be known as a '**Roller Trip Actuated, 3/2 Valve, Spring Return**'



Task 1

Build and test the circuit below.



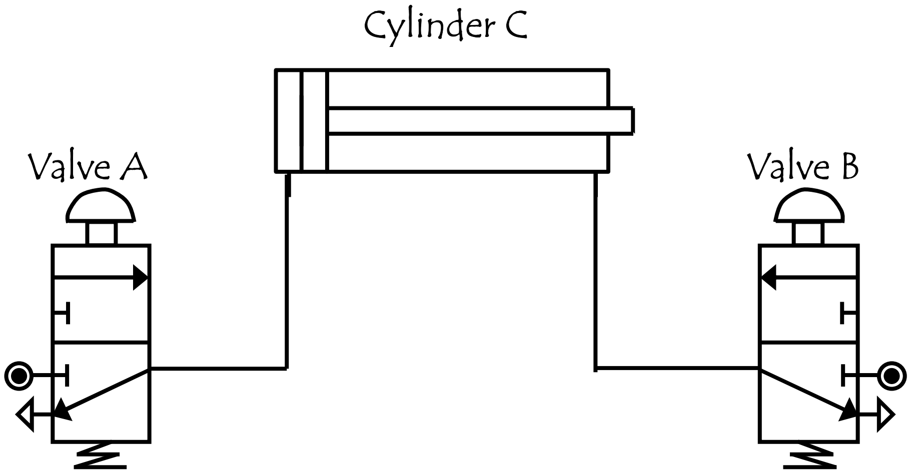
Explain using the correct terminology how this circuit works.

Task 2

Build this circuit using the Airways software. Open unit 2 and select task 2.1. Take a print screen of your model and glue to the space below

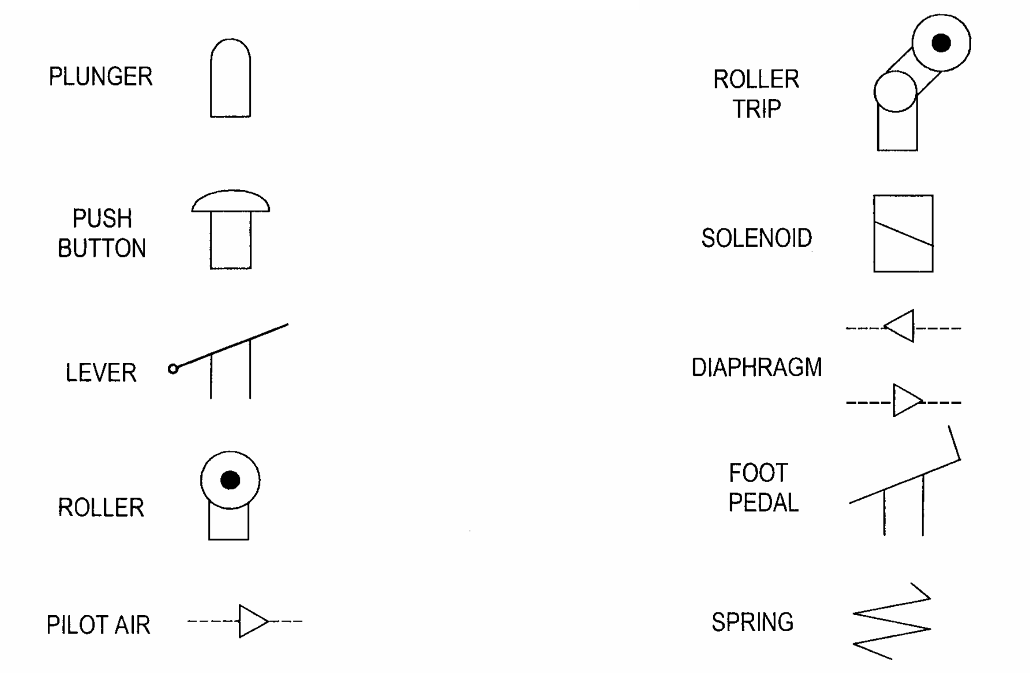
Task 3

Build and test the circuit below.



Explain using the correct terminology how this circuit works.

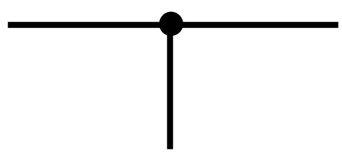
Actuators



There are a number of different ways we can operate a 3/2 valve. The most common types of actuators are shown above

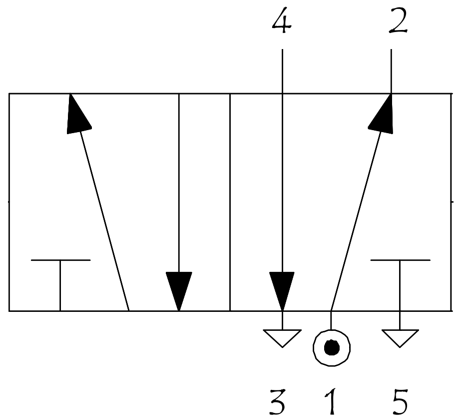
T-Piece

A T-Piece T-connector is a very simple component that lets us split or divide airflow. It can be very useful if you want two cylinders to operate at the same time.
On circuit diagrams, the T-Piece is identified by a dot as shown below;



5/2 valve

There are many problems when controlling a double acting cylinder with 2 3/2 valves, because after you have actuated the 3/2 valve it returns to the off state and therefore no air is being supplied to the cylinder. This will mean it can be moved easily by hand.

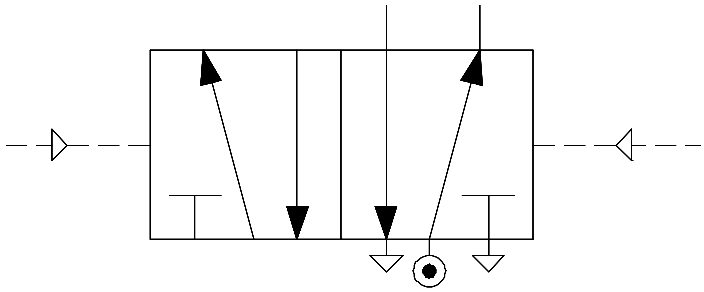


Another disadvantage is that the 3/2 valve needs to be actuated until the cylinder is fully out/in stroked. Releasing the valve will mean the piston will stop short of its final position.

We have greater control over a double-acting cylinder if we control its out/in stroke with a 5/2 valve.
The ports are numbered in the same way as a 3/2 valve except there a re 2 exhaust ports and 2 output connections.

Pilot Air

5/2 valve can be operated in the same way as 3/2 valves. However the most common way of actuating a 5/2 valve is by pilot air. A pilot air valve will change state when a brief air signal acts at either end of the valve.

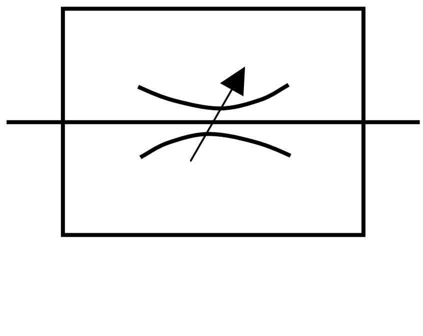


Flow control valves (SPEED CONTROL)

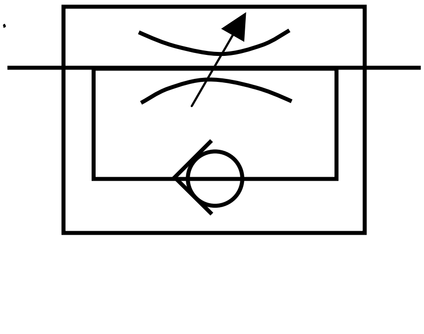
You should have noticed in the circuits you have built so far that the pistons move very quickly. This can be dangerous or it may prevent a circuit working correctly, to slow down the speed of the pistons we use flow control valves.

There are two types;

Restrictor
This slows down the air going through it in both directions.

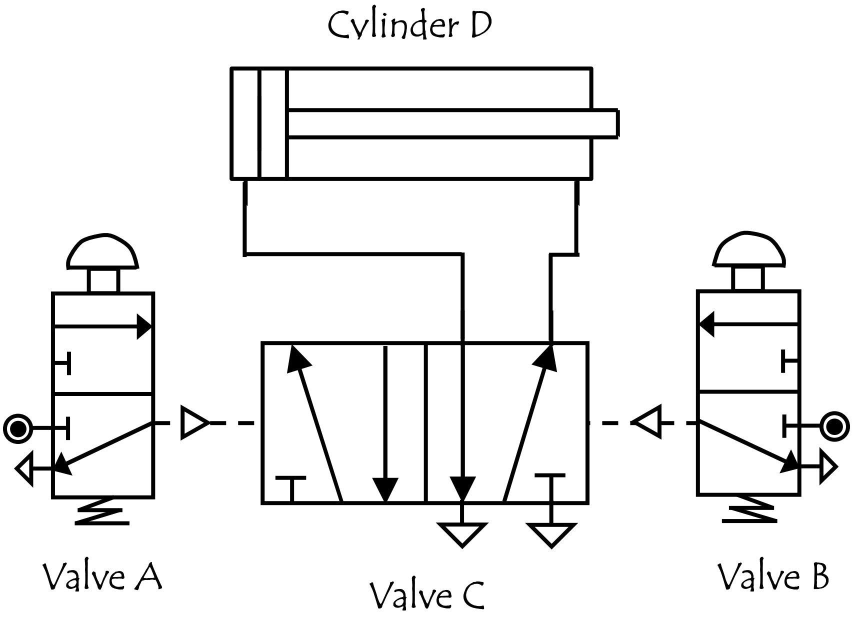


Uni-directional restrictor
This only slows down the air in one direction.



Task 4

Build and test the circuit below.



Take a photo of your model and glue to the space below

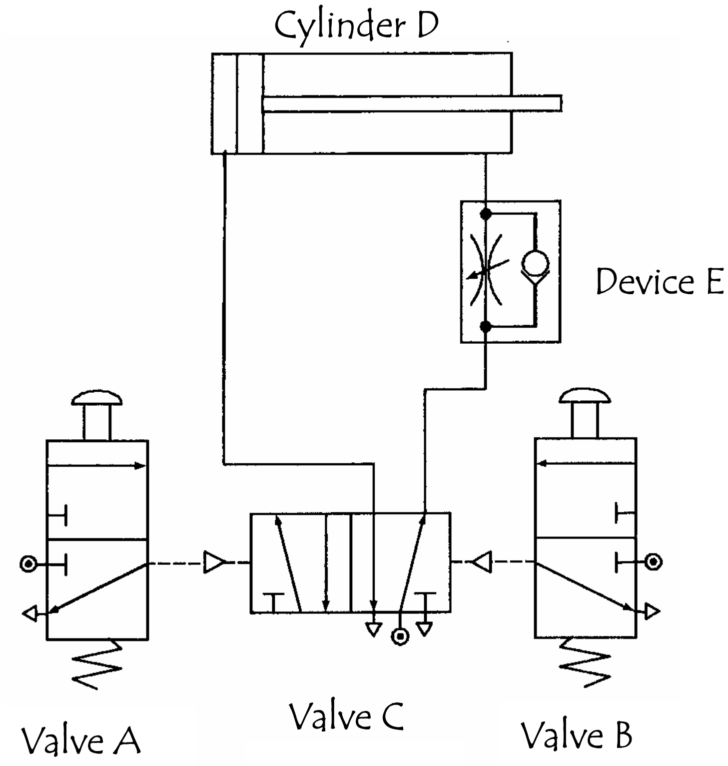
Task 4 Continued)

Explain using the correct terminology how this circuit works.

http://www.bbc.co.uk/schools/gcsebitesize/design/systemscontrol/pneumaticsrev1.shtml

Task 5

Build and test the circuit opposite



Explain using the correct terminology how this circuit works.

http://www.youtube.com/watch?v=LcZcSKUwzjo

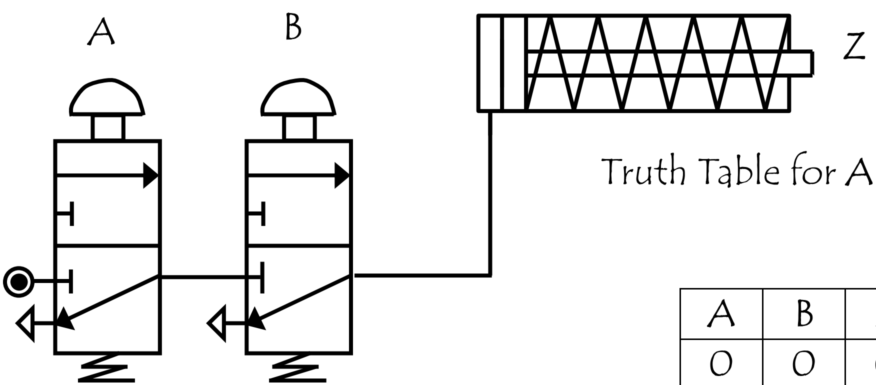
Air Bleeds

Sometimes with the pneumatics we find that the actuators on valves can get in the way of the circuit. Also some actuators need large forces to make them operate which is not always possible.
Air bleeds are often used to overcome this problem in conjunction with s diaphragm valve.
The circuit below shows a circuit, which uses an air bleed to actuate a cylinder.
When the air bleed is blocked the air is diverted down to the diaphragm valve, which activates the 3/2 valve, and in turn the cylinder out strokes.

AND Control

Although pneumatic circuits are very safe, it is important to take safety precautions. AND control circuits can be used to help prevent accidents by ensuring that guards are in position before machines are switched on. These circuits can also be used to stop a machine being switched on accidentally or to stop operators placing their hands in the machine when it is running.

AND control involves connecting 3/2 valves together in *series*. This means that the output from one valve becomes the input to another

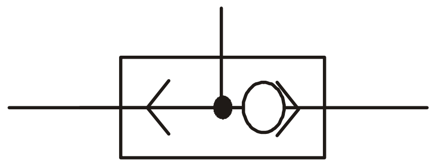


Truth Table for AND gate

A	B	Z
0	0	0
0	1	0
1	0	0
1	1	1

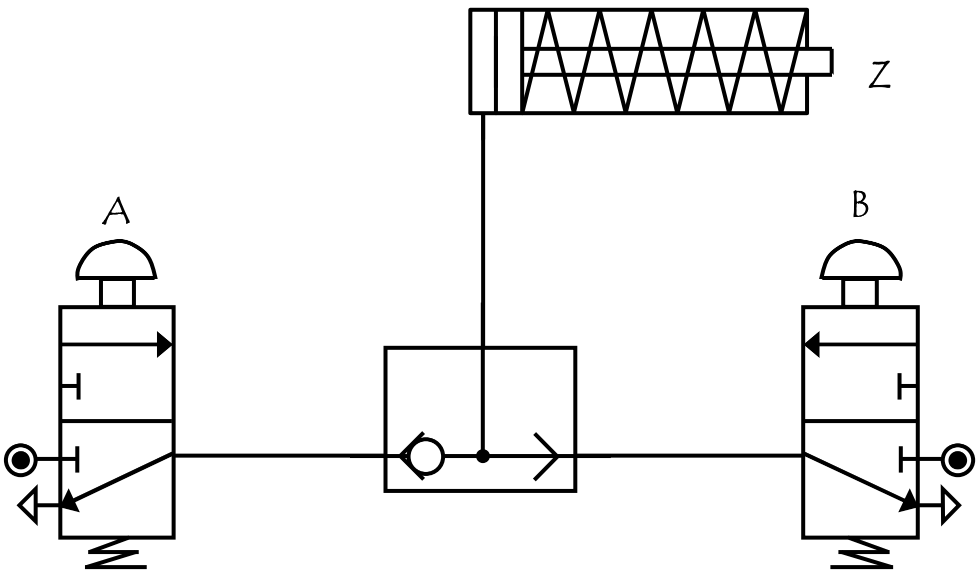
OR Control

Sometimes we need to control a pneumatic circuit from more than one position. This can be done using OR control circuits. These circuits are quite simple but they need another component called a *shuttle valve*.



A shuttle valve is used to change the direction of air in a circuit. It has a small ball inside that gets blown from side to side.

OR control involves connecting 3/2 valves together in *parallel*. This means that either valve will outstroke the cylinder.

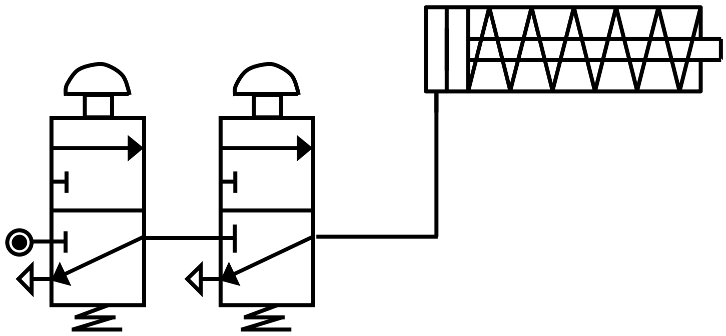


Truth Table for OR gate

A	B	Z
0	0	0
0	1	1
1	0	1
1	1	1

Task 6

Build and test the circuit below.



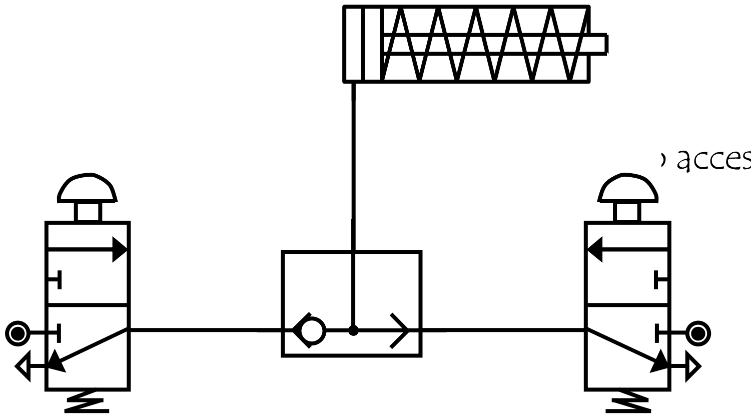
Does it work in the way it is supposed to?

Using the correct terminology explain exactly how this circuit works.

Take a photo of your model and glue to the space below

Task 7

Build and test the circuit below



Does it work in the way it is supposed to?

Using the correct terminology explain exactly how this circuit works.

Take a photo of your model and glue to the space below

Task 8

Using the Airways software open unit 4 and complete task 4.3

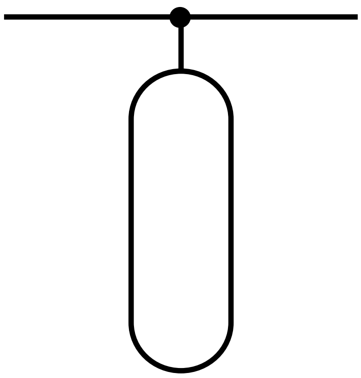
Take a photo of your model and glue to the space below

Using the correct terminology explain exactly how this circuit works.

Time Delays

Normally cylinders respond immediately when a value is actuated.

If you do not want it to respond immediately you can create a time delay by a component called a reservoir. This is simply a container for compressed air. If you connect this to a pipe it increases the space that has to be pressurised before the next component is operated. This created a time delay.



Task 9

Using the Airways software open unit 4 and complete task 4.1

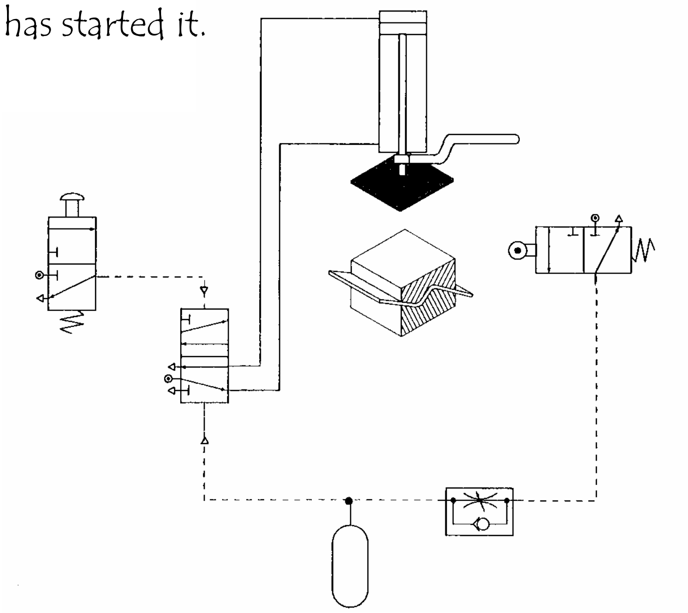
Take a photo of your model and glue to the space below

Automatic Circuits

Automatic circuits are commonly found on production lines. They help speed up production and make sure that goods are all made to the same standard.
There are two types: semi and fully.

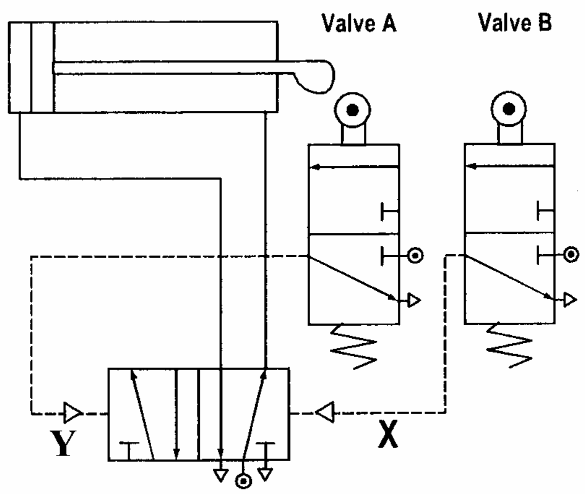
Semi Automatic

A semi automatic circuit is one, which completes a process once a human operator has started it.



Fully Automatic

A fully automatic circuit is one that continues to work, performing a task over and over again.
Automatic circuits produce *reciprocating motion.*
Here is an example of a fully automatic circuit;



Sequential Control

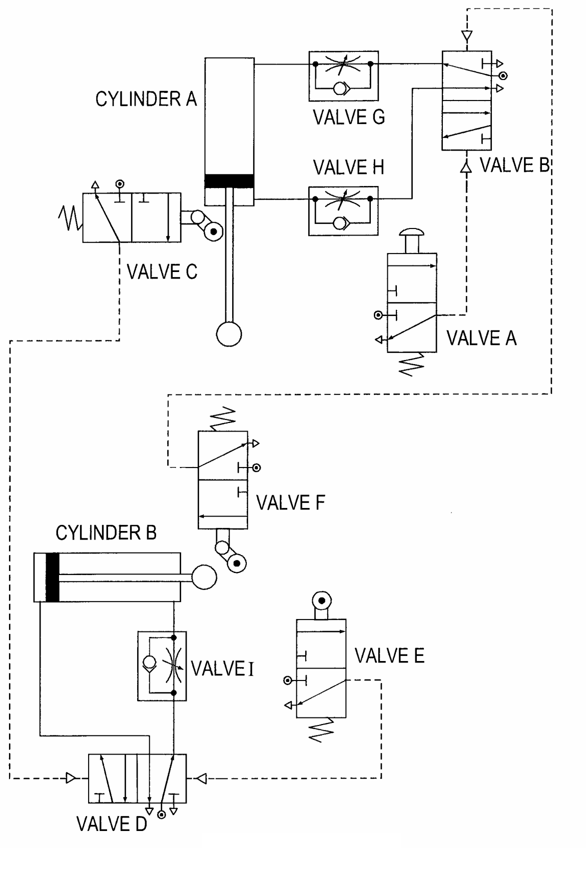
Many pneumatic systems and machines are designed to perform a range of tasks in a certain order or sequence. This usually involves two or more cylinders.

For example;
A company has automated its production line that involves metal blocks being placed in a furnace for heat treatment. One cylinder is used to open the furnace door and another pushes the metal block into the furnace.
The sequence of operations for this process is as follows.

a) An operator pushes a button to start the process.
b) The furnace door is opened
c) The block is pushed into the furnace and the piston in strokes
d) The furnace door is closed
e) The sequence stops

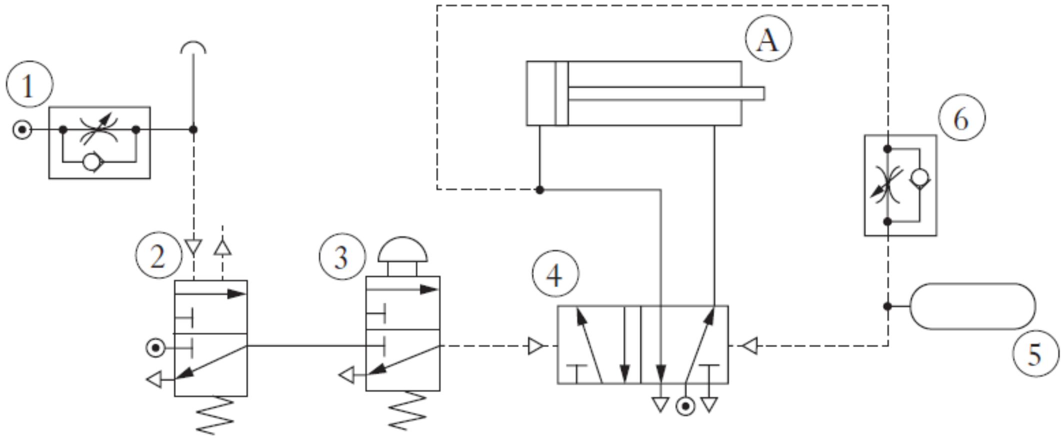
Below is the explanation and circuit diagram for the system;

The system begins by actuating valve A. This changes the state of the valve B and cause cylinder A to in stroke, raising the door. When fully in stroked, or negative, the piston trips valve C and this send a signal to valve D. This 5/2 valve changes state and send cylinder B positive. When fully outstroke, the piston trips valve E and the cylinder in strokes. When negative, valve F is actuated and cause cylinder A to outstroke and stay in the positive position. The system stops and waits for a signal from valve A.



Task 10

A pneumatic circuit used in a production line as shown below



(*a*) State the **full** name of the following pneumatic components.

Component 5:

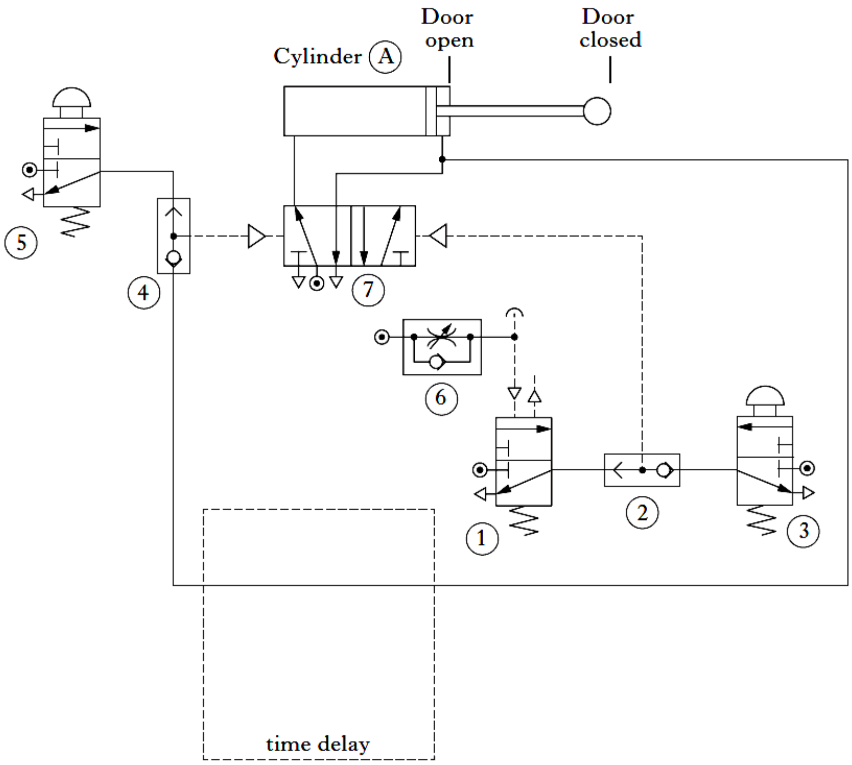
Component 2:

(*b*) Describe, using appropriate terminology, the operation of the pneumatic circuit.

An increase in pressure is sensed . . .

Task 11

The pneumatic circuit for a door system is shown below



(a)State the name of component 1

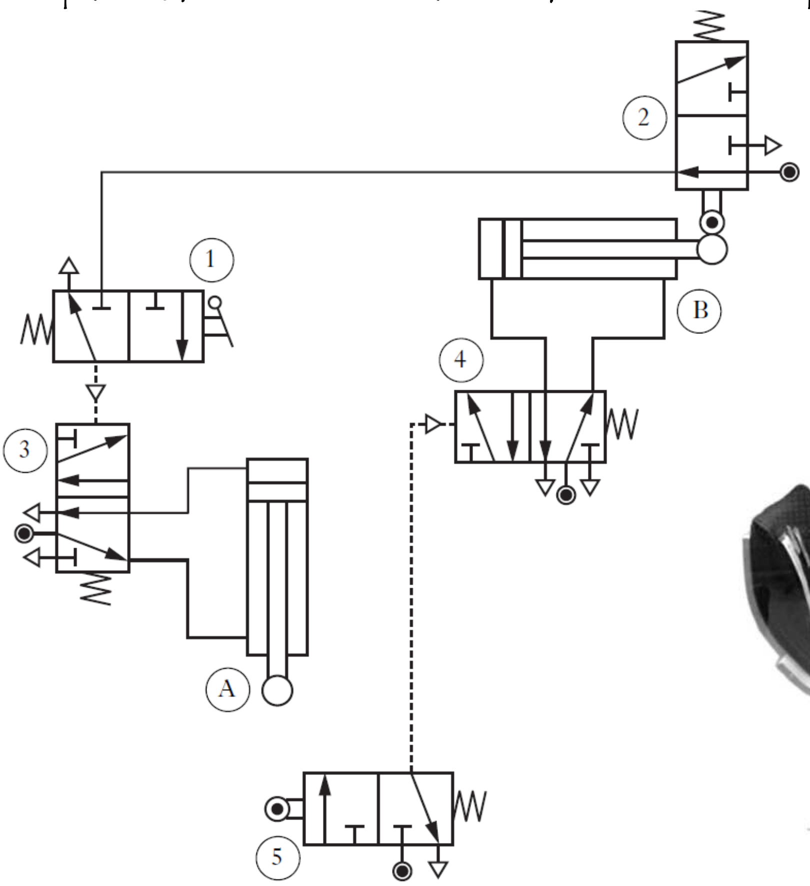
(b) Draw, in the position shown in the above circuit the components required to create a controlled time delay when closing the door.

(c) Describe, using appropriate terminology, the operation of the door system.

When is actuated....

Task 12

The pneumatic circuit shown is used to test the life span of a chair



(*a*) State the full name of the following pneumatic components.

Valve 1:

Valve 3:

(*b*) Describe, with reference to Figure Q8, the operation of the pneumatic circuit.

Valve is actuated….

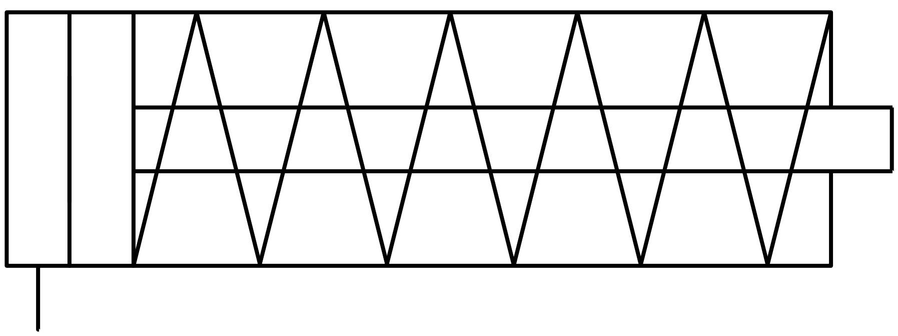
Forces in a Single- Acting Cylinder

When a single-acting cylinder out strokes it produces force.

We can use this force to carry out tasks. When designing pneumatic circuits, we must use a cylinder that is capable of completing its task. For example, if a single-acting cylinder is used to push parcels off a conveyor belt, then it must produce a big enough force to be able to do this. If the force is not big enough, the parcels will not move, and if the force is too big, the parcels may be damaged.

The size of the force produced by the cylinder as it out strokes depends on two things- air pressure applied to the cylinder and the surface area of the piston. This means that if we want a bigger force *we can either use a larger piston or increase the air pressure.* However, it is not a good idea to increase the air pressure because this can cause damage.

The in stroke of a single-acting cylinder is controlled by a spring. The spring returns the piston to its original position. We do not normally use the in stroke of a single-acting cylinder to carry out tasks.



Pressure

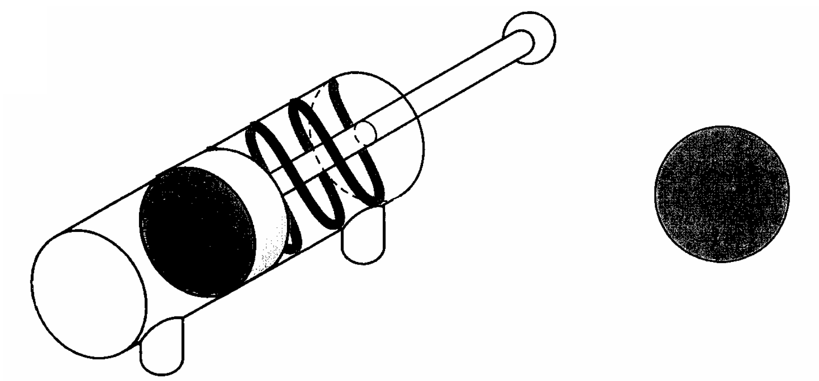
Air pressure is measured in *Bars or in N/mm2.* We can measure the pressure in a pneumatic system using a pressure gauge. A gauge will always be connected in a compressor, but other gauges maybe connected throughout large systems. *This helps to detect leaks, as the pressure in the system would begin to fall if air was escaping from the pipes.*

In pressure calculations we require the units to be in N/mm2, if the vales are in bars it must be converted, the chart below provides a quick reference.

Area

The surface of the piston is the area that the air pushes against to outstroke the piston. This area is circular.

The area of a circle is calculated using the formula; Area = πr^2



Force

The force produced when a single-acting cylinder out strokes is calculated using the formula;

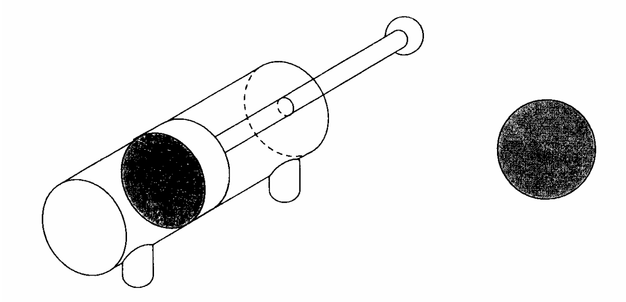
Force = Pressure x Area

When force is measured in Newton's, pressure in N/mm2 and area is measured in mm2.

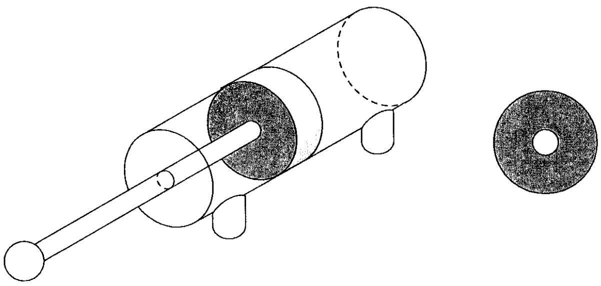
Forces in a double-acting cylinder

We already know a double-acting cylinder can be more useful to us because the input and output strokes are controlled by compressed air. This allows us to make use of both the out strokes and in strokes force.

What we learn however is that the out strokes force is greater than the in stroke force.



However, during the in stroke the surface area is reduced because of the piston rod. This means that the compressed air does not have as big an area to push against and so it does not produce as big a force.



We can find thus surface area or *effective area,* as calculating the area of the piston rod and subtracting it from the area of the piston know it.

Effective Area = piston area – piston rod area

http://www.youtube.com/watch?v=2xOds3rR5ew

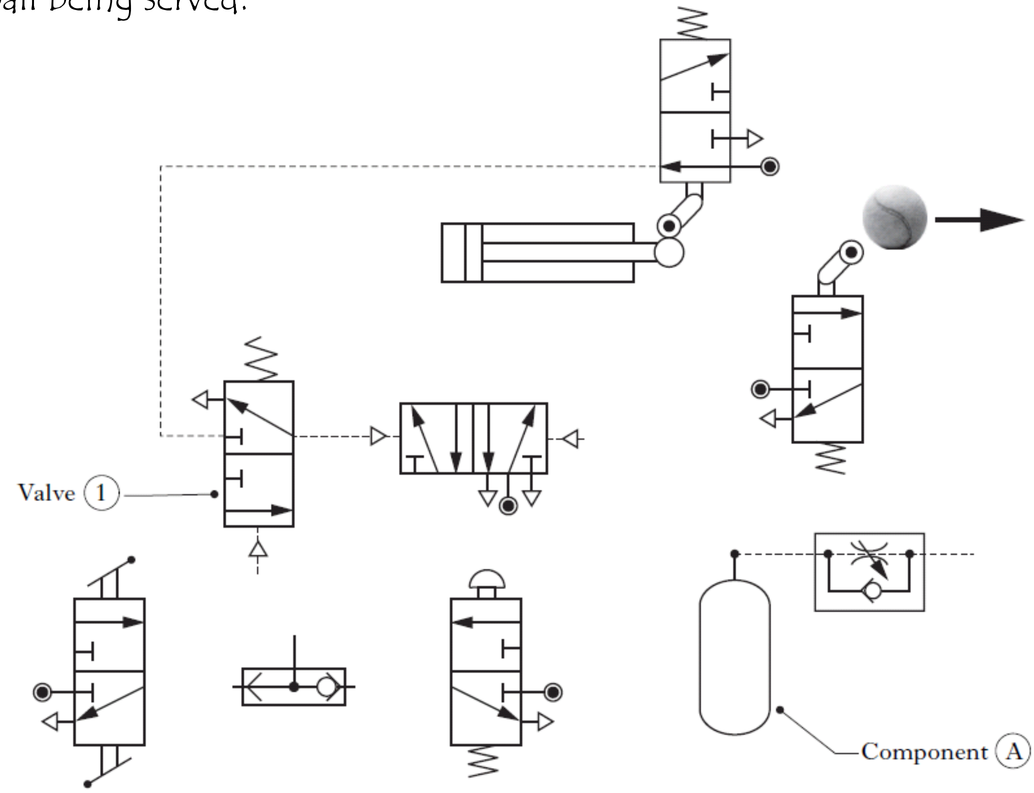
Task 13

Using the Airways software complete unit 8

Task 14

A pneumatic circuit is used to serve tennis balls during practice sessions.

The system will serve automatically when a lever is actuated or manually each time a button is pressed. There is a delay between each ball being served.



(a) Complete the piping of the pneumatic circuit.

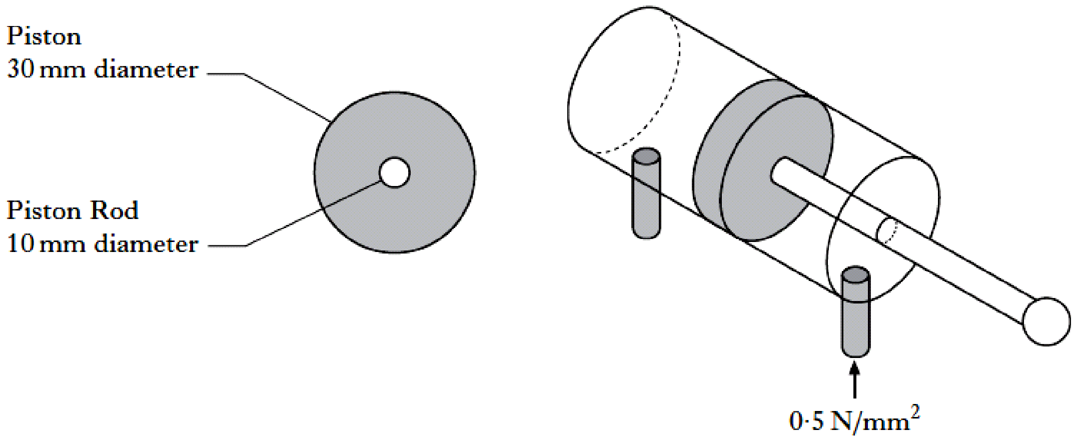
(b) State the full name of the following components.

Component A:

Valve 1:

Task 14 – Continued

The piston below **instrokes** when air is supplied at a pressure of 0.5N/mm2 to the cylinder.



(c) Calculate the in-stroking force.

(d) Describe **two** ways of reducing the **out-stroking** force applied by a piston.

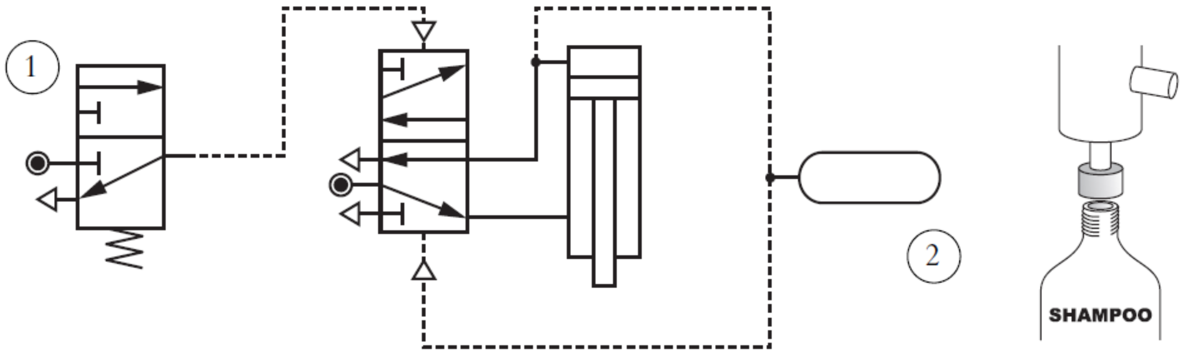
1 ____

2 ____

http://www.bbc.co.uk/apps/ifl/schools/gcsebitesize/design/quizengine?quiz=pneumaticstest&templateStyle=design

Task 15

Below shows an incomplete pneumatic circuit used to fix tops on shampoo bottles.



Valve is to be actuated by an electrical signal.

(*a*) (i) State the name of this actuator.

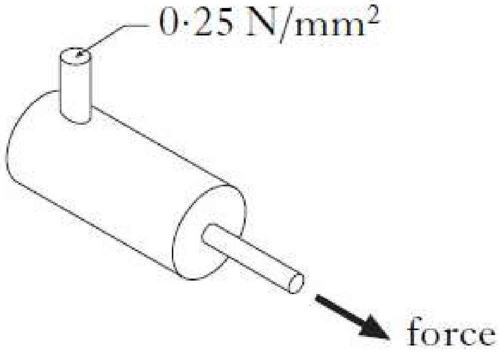
(ii) Sketch the symbol for this actuator below.

(*b*) (i) Sketch on the circuit above the pneumatic device that will create an adjustable time delay after the piston outstrokes.

(ii) State the name of component

Task 15 (Continued)

A 10 mm diameter cylinder has air supplied at a pressure of 0.25N/mm2.



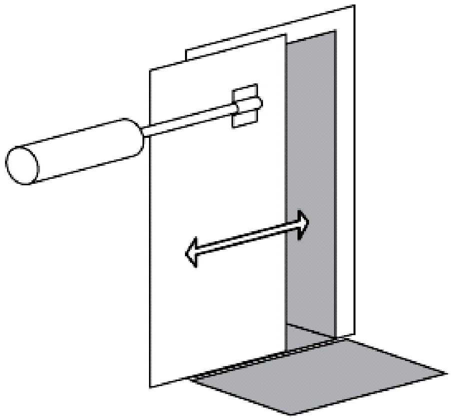
(*c*) Calculate the force of the piston as it outstrokes.

(*d*) Explain why the in-stroke force of the piston will be less than the out-stroke force.

(*e*) State a reason, other than cost, for using pneumatic systems in an industrial environment.

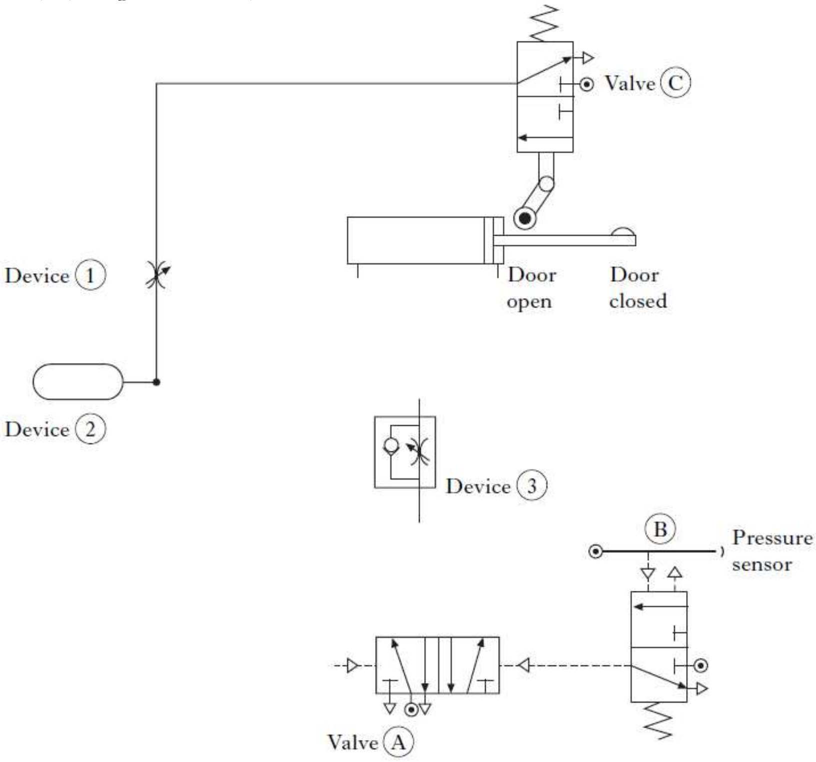
Task 16

A pneumatic circuit is used to control the operation of an automatic door

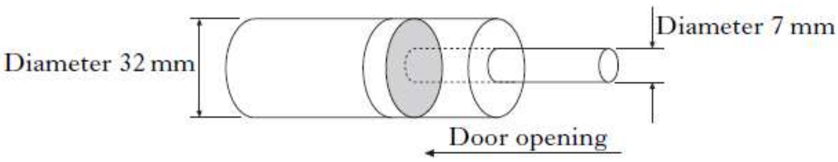


When a person steps on to the pressure sensor, the piston will in-stroke and open the door. After an 8 second delay, the piston will automatically outstroke and slowly close the door.

(a) Complete the piping of the pneumatic circuit below.



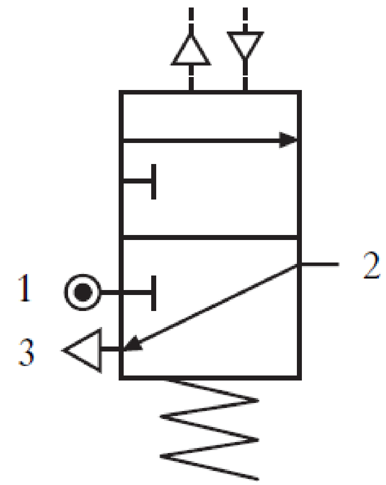
(b) Calculate the in-stroking force when the air pressure is 2.32 N/mm^2.



http://www.youtube.com/watch?v=clvwU-tVGtM

Task 17

The symbol for a pneumatic valve is shown below



(a)

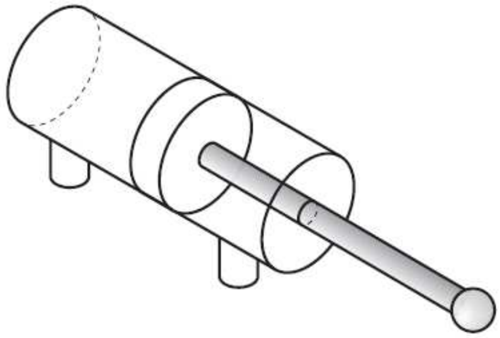
(i) State the full name of the pneumatic valve.

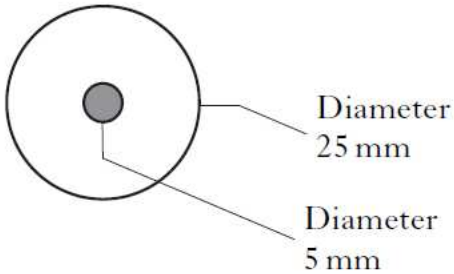
(ii) Complete the table below for the valve ports.

Port	Connection
1	
2	Output port
3	

Task 17 (Continued)

Below shows the dimensions of a double acting cylinder.





(*b*) Calculate:

(i) The effective area of the piston as it in-strokes;

(ii) the in-stroking force of the piston if air is supplied at a pressure of 0·6N/mm2.