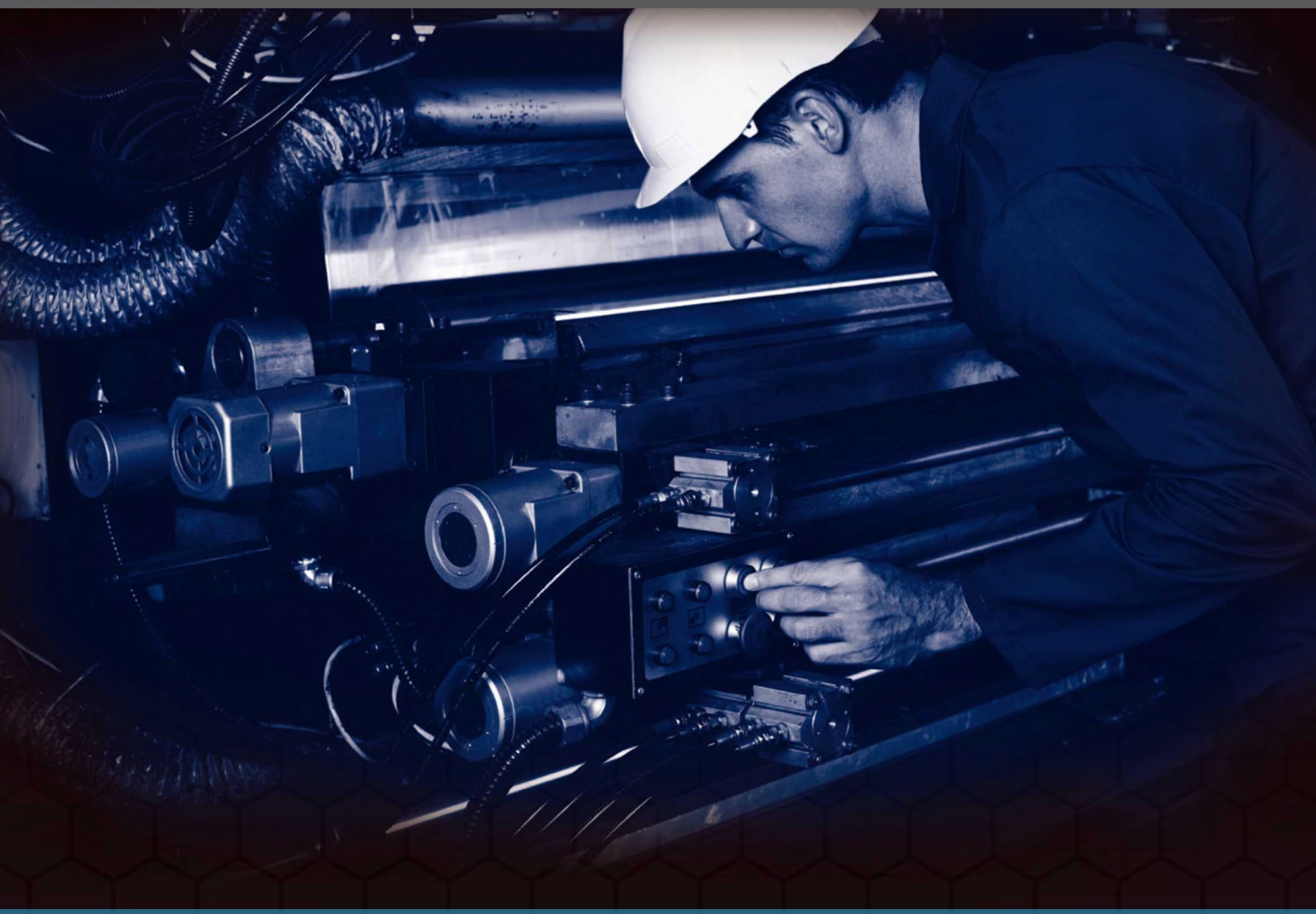
MATRIX | PNEUMATICS



ELECTRO-PNEUMATICS

CP2079

Inspiring The Next Generation Of Engineers

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Introduction

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WORKSHEETS

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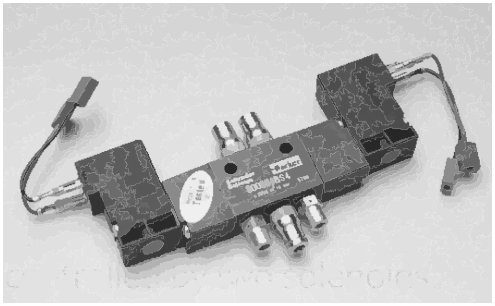
WORKSHEETS

Worksheet 1 – Electronic Control

In the earlier 'Pneumatics essentials' module, compressed air controlled everything, including the control gear itself. It is often simpler to use electronic circuitry to do the controlling, and use the compressed air to do the moving. For one thing, electronic components are often smaller than pneumatic actuators.

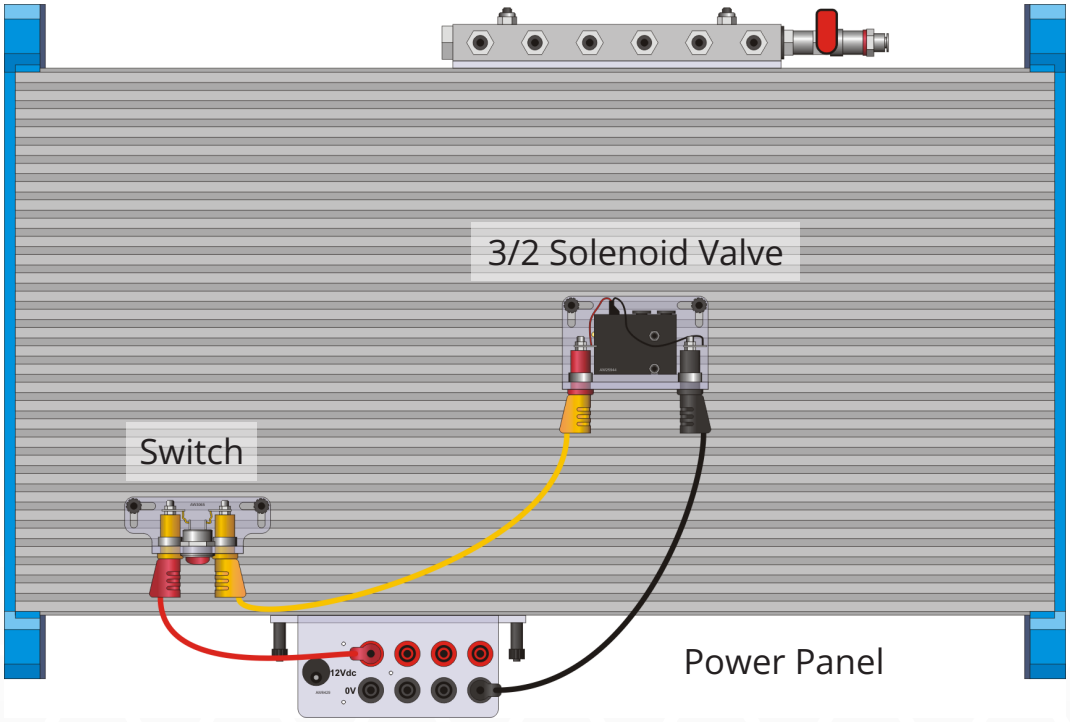
- Electronics makes it relatively easy to:
- extend and retract cylinders in any sequence;
- include timing and counting;
- make the system respond to sensors.



The picture shows a 5/2 valve, with exhaust restrictors,

Over to You

- Build the arrangement shown below. It demonstrates electronic control of pneumatic valves. There are no pneumatic connections, only electrical ones!
- Clamp a switch and a 3/2 solenoid valve to the platform.
- Make the following connections:
- power panel - plug in 12V power supply;
- switch - one socket to power link panel red
  - one socket to 3/2 spring solenoid valve red socket;
- solenoid valve - black socket to power link panel black.
- Plug in the power supply and switch it on
- Press the switch. You should hear the solenoid operate inside the control valve.



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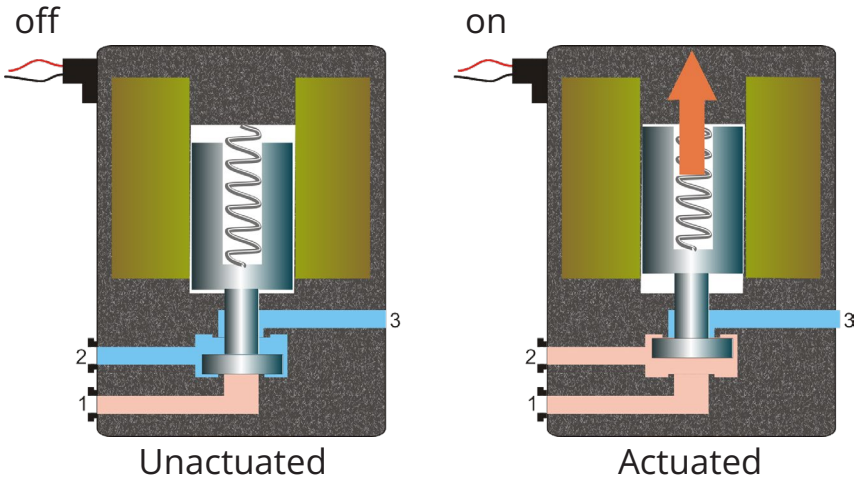
WORKSHEETS

Worksheet 1 – Electronic Control

So What:

The valve used here is a three port solenoid/spring valve. Pneumatically, it operates in the same way as the one used earlier in the 'Pneumatics essentials' module. The difference? - it is actuated by a solenoid.
A solenoid is made by inserting an iron core into the centre of a coil of wire. When an electric current passes through the wire, a magnetic field is set up which makes the iron core acts like a magnet. This is called energising the solenoid.
When the solenoid in the valve is energised, it moves the spool into its actuated position. When it is de-energised, a spring inside the valve moves the spool back to its unactuated position.

Key:
1= inlet port
2= outlet port
3= exhaust



Unactuated Actuated

The diagrams illustrate the principles of solenoid operation.

For your records:

- Set a multimeter to measure voltages up to 12V.
- Use it to measure the voltages listed in the table below.
- Then copy and complete it.

Quantity	Voltage	Solenoid Actuated?
Solenoid red socket - switch not pressed		
Solenoid red socket - switch pressed		

- Write a short explanations, each less than fifty words, to make clear to a fellow-student how:
  - a solenoid works;
  - a solenoid valve works.

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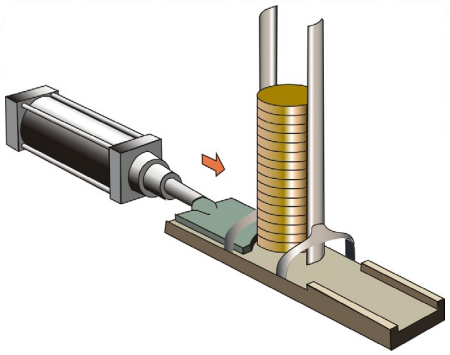
WORKSHEETS

Worksheet 2 – Magazine Feed

In automated production, it is often necessary to feed blanks into the process from a store, known as a magazine.
Pneumatics offers a reliable and speedy way to do this, as the diagram illustrates. A single-acting cylinder pushes a new blank onto the conveyor belt, and then retracts.
This worksheet examines how an electronic control system can operate this part of the process.



Over to You

- Read the safety rules given on the next page before you start.
- The red lever on the manifold must be turned off at this stage.

- Build the arrangement shown on the next page. Compare the physical and pneumatic circuit diagrams, as you do so.

    - Clamp a switch and a 3/2 solenoid valve to the platform.
    - Add a flow-control valve, to restrict flow in the direction shown by the arrow.
    - Make the following electrical connections:
        - power panel - plug in 12V power supply;
        - switch - one socket to power link panel red
        - - one socket to 3/2 spring solenoid valve red socket;
        - solenoid valve - black socket to power link panel black.

- Plug in the power supply (12V), and switch on.
- Turn on the air supply.
- Press the switch. The cylinder extends.
    - This delivers a new blank onto the conveyor.
- Release the switch, The spring retracts the cylinder.
    - This returns the cylinder to the start position, ready to start again.
- Adjust the flow control valve so that the cylinder extends at a moderate speed.

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WORKSHEETS

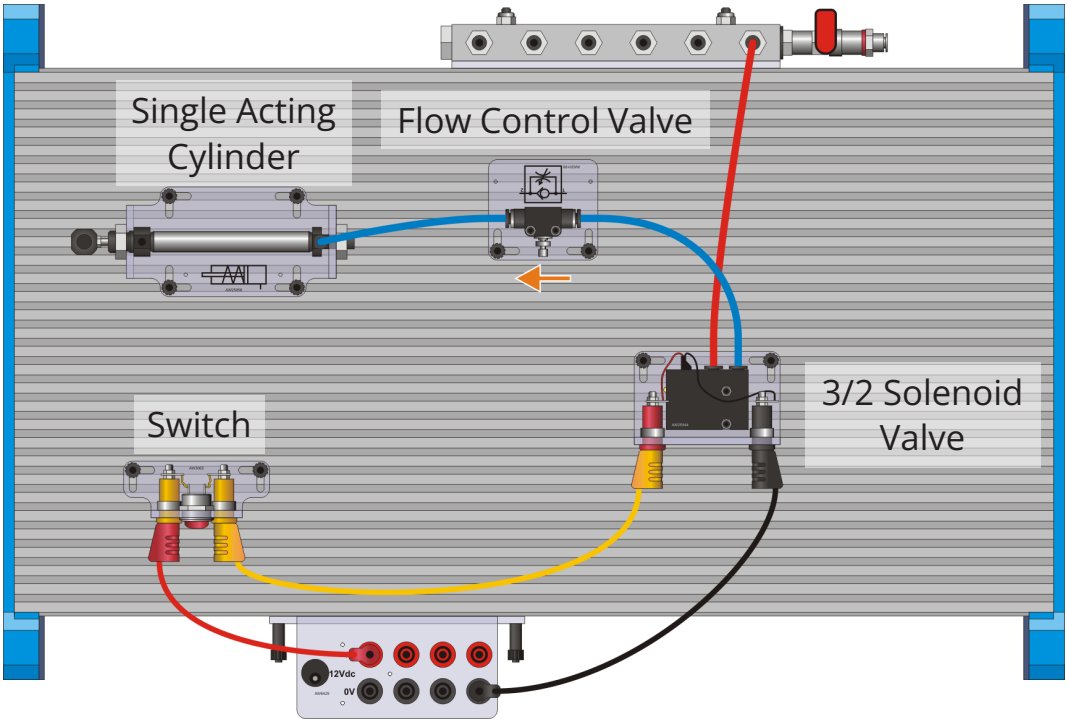
Worksheet 2 – Magazine Feed

Safety Rules for Pneumatic Systems

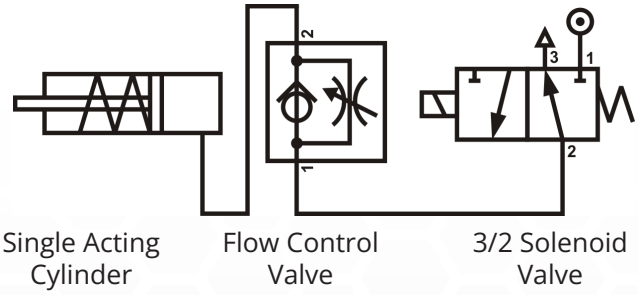
Remember: compressed air and its components are capable of exerting large forces.

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.

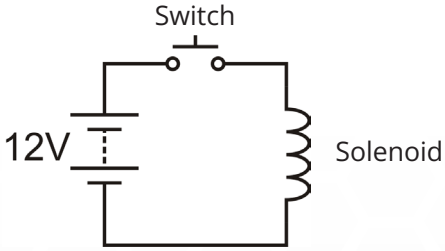
System for worksheet 2:



Physical Layout



Pneumatic Circuit Diagram



Electrical Circuit Diagram

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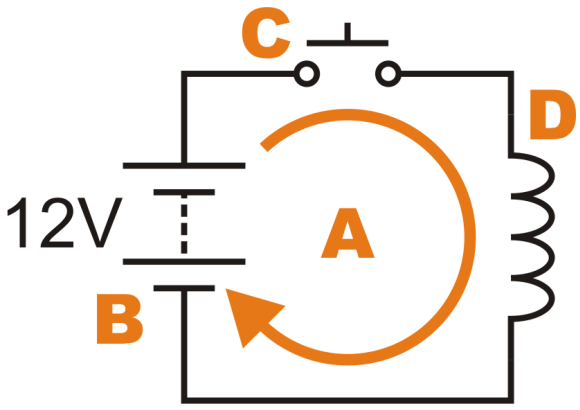
So What:

Electrical circuit diagrams:

- perform the same job for electrical systems as pneumatic circuit diagrams do for pneumatic systems;
- use a different set of symbols.

Electrical circuit diagram for worksheet 2:



A - In a pneumatic system, air is taken from the atmosphere, compressed, used to perform the required task and then exhausted back to the atmosphere.
Electrical circuits behave more like hydraulic circuits, in that they contain closed loops. Electricity requires a complete circuit. Electrons leave the power source with excess energy. They transfer this to the components they pass through before returning to the power supply for more energy.
In the circuit diagram, **A** shows this complete circuit.

B - The greater the power supply voltage, the greater the energy given to the electrons. Sometimes, the power supply symbol is shown as two circles

C - This is the symbol for a push (or momentary-acting) switch.
When closed (pressed,) it allows the electric current to pass.
When open (off,) it blocks any current flow.

D - This the circuit symbol for the solenoid (a coil of wire.)
Sometimes it is shown, as opposite, with two straight lines running alongside.
This signifies that it has an iron core, to intensify the magnetic field.

For your records:

- Copy the pneumatic circuit diagram given above.
- Add an explanation of how the system works, in less than one hundred words.
- How would you make the cylinder extend more quickly?
- How would you modify the system so that it operates only if a safety switch is pressed as well as the operating switch? Draw the electrical circuit diagram for your modified system.

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WORKSHEETS

Worksheet 3 – Bank Vault Door Controller

Bank vaults often have heavy steel doors for enhanced security. Their weight makes them difficult to move manually.
They can be opened and closed pneumatically, using a double-acting cylinder.
This can be linked to an electronic security system, requiring a correct PIN number, finger-print or retina scan.
This worksheet looks at the control system for the pneumatic circuit.

Over to You

- Make sure that you apply the safety rules given in the previous worksheet!
- The red lever on the manifold must be turned off at this stage.

- Build the arrangement shown on the next page, and once again, compare the physical and pneumatic circuit diagrams.

  - Make the following electrical connections:
    - power panel - plug in 12V power supply;
    - switch **1** - one socket to power link panel red
    - - one socket to valve **1** red socket;
    - switch **2** - one socket to power link panel red
    - - one socket to valve **2** red socket;
    - valve **1** - black socket to power link panel black;
    - valve **2** - black socket to power link panel black.

- Plug in the power supply (12V), and switch on.
- Turn on the air supply.
- Press and hold down switch **1**.
  - The cylinder extends, to open the vault door.
- Adjust the flow rate with flow control valve **1** so that it extends at a moderate speed.
- Press and hold down switch **2**.
  - The cylinder now retracts to close the door.
- Adjust flow control valve **2** so that it retracts at moderate speed.

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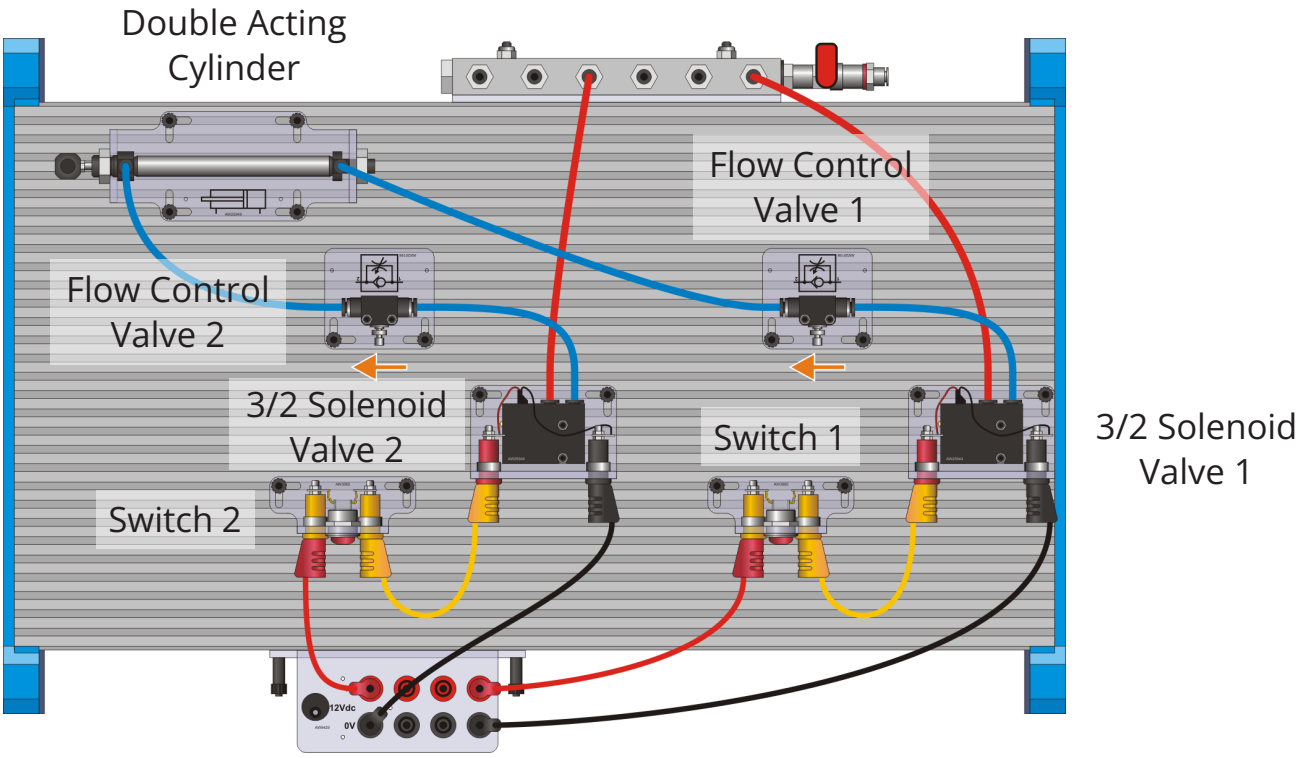
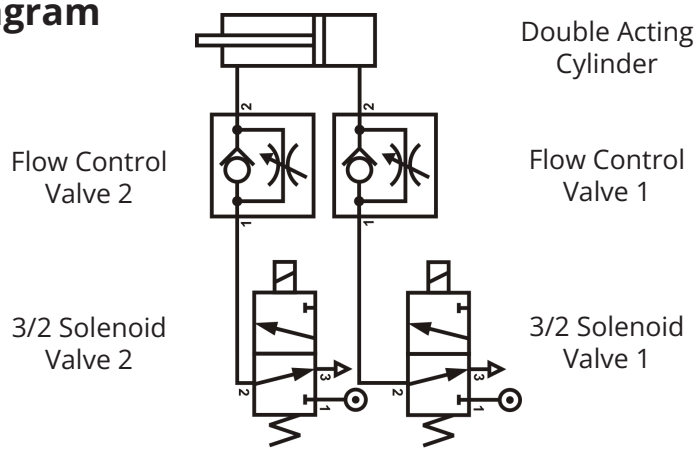
System for worksheet 3:

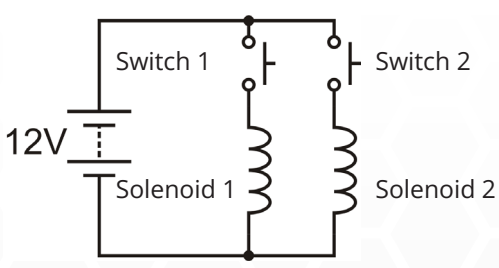
Physical Layout

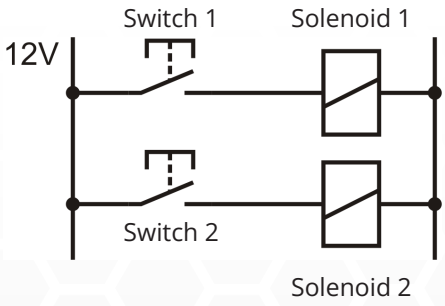


Pneumatic Circuit Diagram



Electrical Circuit Diagram





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WORKSHEETS

Worksheet 3 – Bank Vault Door Controller

So What:

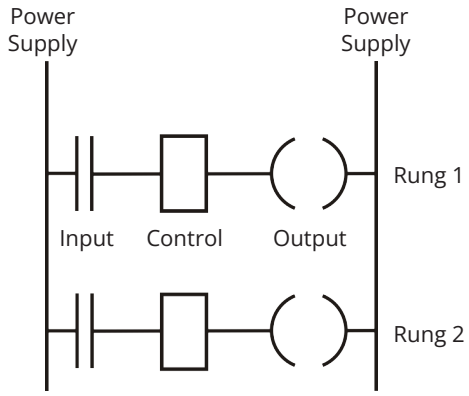
Electrical circuit diagrams:

Standard circuit diagram:

The diagram shows two switch / solenoid sets connected 'in parallel.' In this way, they operate independently, as each set is connected directly to the power supply.

Ladder logic diagrams:

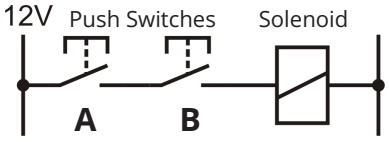
- are simplified circuit diagrams, used originally to design control systems using relays;
- are now more often associated with the use of PLC's (programmable logic controllers,) used to control pneumatic equipment.
  - (These control systems are studied in detail in the Matrix 'Pneumatics control' module.)
- resemble ladders, with vertical rails and horizontal rungs; each rung a separate electrical circuit acting independently, in a form of 'parallel processing.'
- consist of five elements:
  - a power supply - the two vertical rails;
  - input devices, e.g. switches, in the left-hand section of the rung;
  - control devices, e.g. timers in the centre;
  - outputs, e.g. relay solenoids, in the right-hand section;
  - interconnecting wires;
- use symbols which vary between PLC manufacturers;



The second ladder diagram shows the modification suggested in the 'For your records' section in the last worksheet.

Here, a safety switch, **A**, must be closed before the operator's switch, **B**, can work.

Switches **A** and **B** are connected in what is known as a 'logical AND' configuration - **A** AND **B** must be closed to operate the solenoid valve.



For your records:

- Explain why a double-acting cylinder is better than a single-acting cylinder for this application.
- The introduction hints at security features that could be incorporated. Explain, in less than 100 words in total, the advantages and disadvantages of the following forms of security:
  - PIN;
  - retinal scan.

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WORKSHEETS

Worksheet 4 – Feedback Needed

The systems created so far operate blindly, without knowing whether the pneumatic cylinders respond or not.
In practical systems, it is often important to know the position of the piston in a cylinder. This requires 'feedback', positional information returned from the actuator to the control system.
There are a number of ways to do this. One uses a reed switch to provide the feedback. This relies on the piston being magnetised
This worksheet demonstrates how to use reed relays in this way.

Over to You

- Make sure that you apply the safety rules given earlier!
- Make sure that the red lever on the manifold is turned off.

- Build the arrangement shown on the next page. The physical layout is included to help with the positioning of the reed switches. Compare it with the pneumatic circuit diagram.
- Make the following electrical connections:
  - power panel - plug in 12V power supply;
  - switch **S1** - one socket to power link panel red;
  - - one socket to lower socket on reed switch **S2**;
  - reed switch **S2** - upper socket to solenoid **1** red;
  - reed switch **S3** - upper socket to solenoid **2** red;
  - - lower socket to power link panel red;
  - solenoid **1** - black socket to power link panel black;
  - solenoid **2** - black socket to power link panel black;
-
- Plug in the power supply (12V), and switch on.
- Then turn on the air supply.
- Press and hold down switch **S1**. The cylinder should now extend and retract repeatedly, until you release switch **S1**.
- Adjust the exhaust restrictors on the control valve so that the piston moves in and out at a moderate speed.

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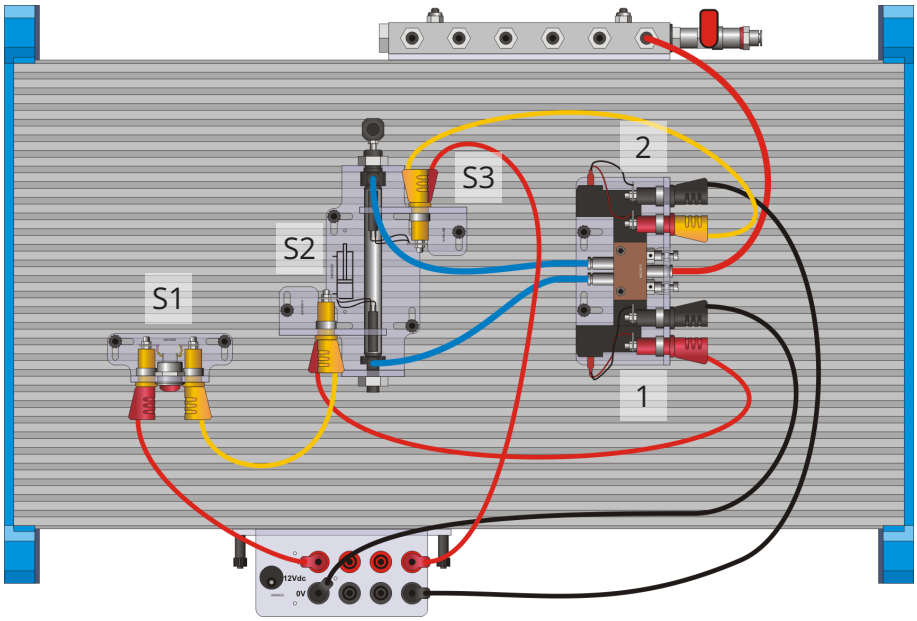
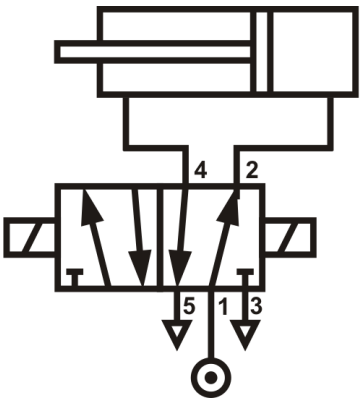
WORKSHEETS

Worksheet 4 – Feedback Needed

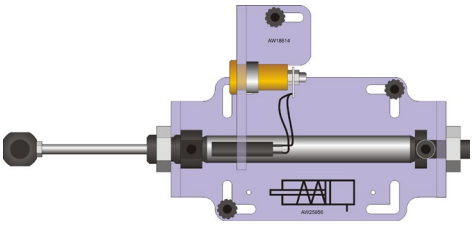
Physical Layout

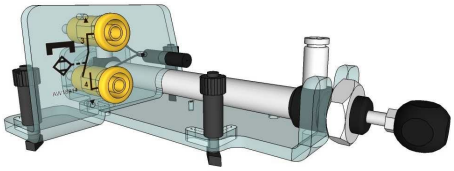


Pneumatic Circuit



The diagrams opposite show in more detail how to connect a reed switch to the cylinder.

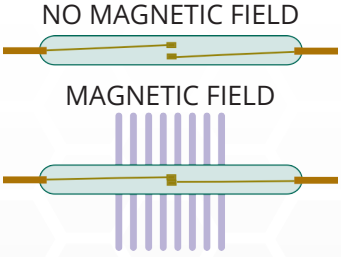




So What:

- The system uses a 5/2 solenoid/solenoid valve to control the double-acting cylinder. This is similar to the 5/2 pilot/pilot control valve introduced in the 'Pneumatics Pneumatics' module, the difference being that it uses solenoids instead of pilot pressure lines.

- It also uses two reed switches to detect the position of the piston in the cylinder. The diagram opposite illustrates the behaviour. The magnetised piston temporarily magnetises the contacts inside the reed switch, causing them to attract each other, and stick together.
- The result is that the reed switch 'switches on'.



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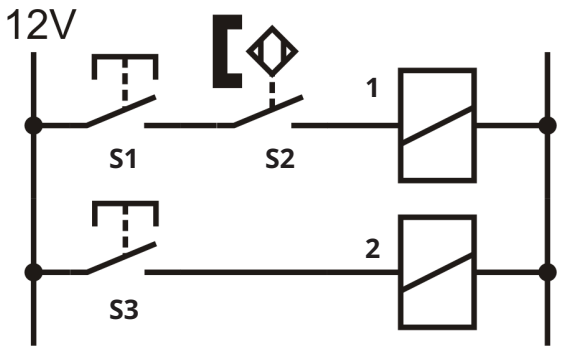
So What:

The ladder diagram for this system is shown below.
It includes the following symbol for the reed switch:

- Nothing happens until push switch **S1** is closed.
- When reed switch **S2** is closed as well, solenoid **1** is switched on.
- This extends the cylinder, causing reed switch **S3** to close, switching on solenoid **2**.
- This causes the cylinder to retract, opening **S3** and closing **S2**.
- This cycle repeats as long as **S1** is closed.



For your records:

The reed switch is one form of position sensor but there are other types.

Find out as much as you can about the following categories of proximity and position sensors:

- inductive sensors;
- capacitive sensors;
- optical sensors.

For each, write a short description, including:

- how the sensors work;
- the relative advantages and disadvantages;
- typical applications.

Your descriptions should be no longer than 100 words for each type.

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WORKSHEETS

Worksheet 5 – In Sequence

Many applications of pneumatics require two, or more, cylinders to operate together in a sequence.
The next pneumatic control system operates a gripper, which could be part of a robot arm.
The gripper reaches out and brings back an object, such as a cup, when a switch is pressed.
It relies on two pneumatic cylinders, A and B, working in the following sequence:

- reach out (A extends);
- grip (B extends);
- bring back (A retracts);
- release (B retracts).

Over to You

- Make sure that you apply the safety rules!
- Make sure that the red lever on the manifold is turned off.

- Build the arrangement shown on the next page.
- The three diagrams show the pneumatic circuit, the ladder diagram (electrical circuit) and a suggested physical layout for the components. The electrical connections are missing from the physical layout to make it clearer.
- Use the ladder diagram to make the electrical connections needed.
- Position the two micro switches carefully. The one labelled **a-** is closed when cylinder **A** is fully retracted, but opens as soon as the cylinder extends. The one labelled **a+** is closed when cylinder **A** is fully extended, but opens as soon as the cylinder retracts. The physical layout shows a 'ghost' image of cylinder A extended, to illustrate this.
- Plug in the power supply (12V), and switch on.
- Then turn on the air supply.
- Press and hold down switch **S1**. The cylinders should now extend and retract in sequence repeatedly, until you release **S1**.
- Adjust the exhaust restrictors and flow control valves so that the pistons move in and out at moderate speed.

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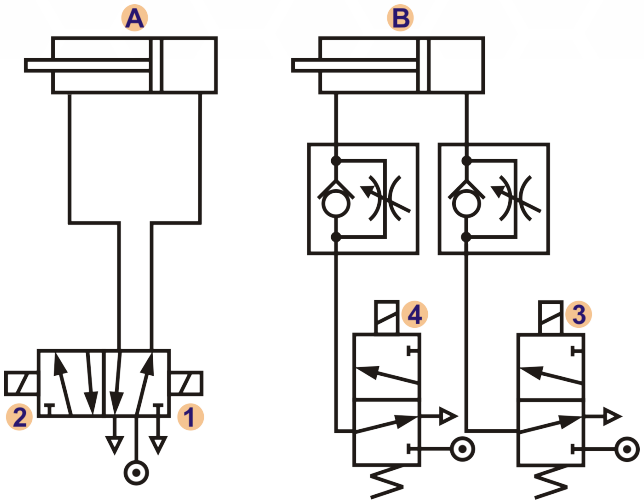
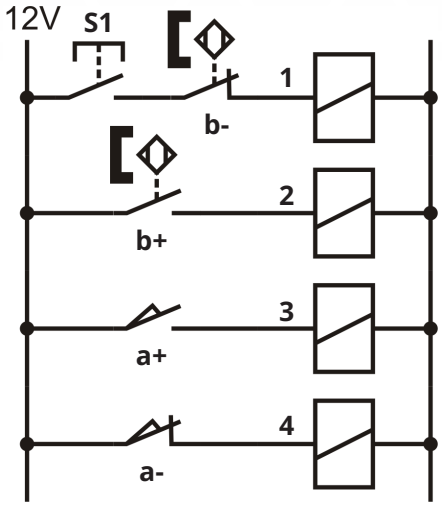
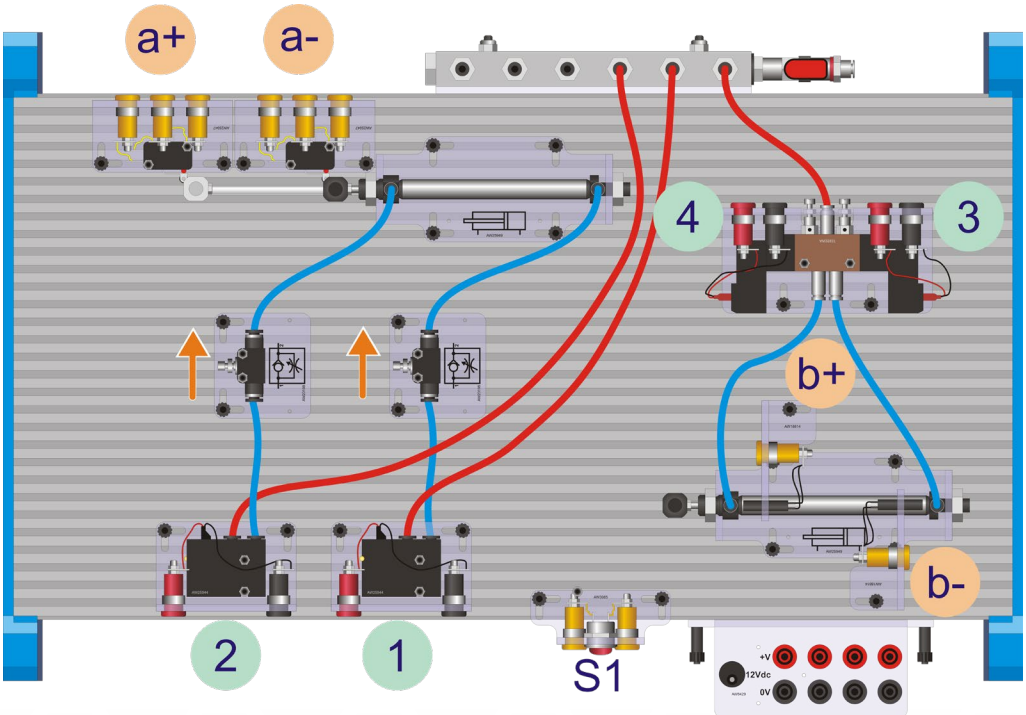
Pneumatic Circuit Diagram



Ladder Diagram





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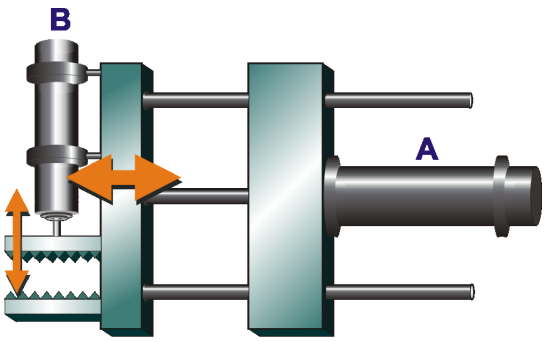
WORKSHEETS

Worksheet 5 – In Sequence

So What:

The two cylinders that control the gripper operate in the sequence:

- reach out (**A+**);
- grip (**B+**);
- bring back (**A-**);
- release (**B-**).



It is important to identify clearly the four switches (**a-, a-, b+** and **b-**,) and the four solenoids (**1, 2, 3** and **4**,) on your assembly.

- Solenoid **1** extends cylinder **A**;
- Solenoid **2** retracts cylinder **A**;
- Solenoid **3** extends cylinder **B**;
- Solenoid **4** retracts cylinder **B**.

The sequence is determined by how you connect these switches to the solenoids. The ladder diagram shows that, here, switch **b-** controls solenoid **1, b+** controls solenoid **2, a+** controls solenoid **3** and **a-** controls solenoid **4**.

The ladder diagrams in this and the previous worksheets include new symbols:


reed switch - normally open


reed switch - normally closed


micro switch - normally open


micro switch - normally closed

For your records:

- Copy the ladder logic symbols for:
  - a push switch;
  - a solenoid;
  - a reed switch (normally open);
  - a micro switch (normally open.)

- Draw the ladder diagram, for the same physical layout, to generate the following sequence when switch **S1** is pressed:

  A+ A- B+ B-

- Build and test your design.

- What sequence would be required to control an air lock, where cylinder A operates the outer door, and cylinder **B** the inner door? Draw a ladder diagram for your proposed solution, and explain each stage of the sequence as part of your answer.

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About These Questions

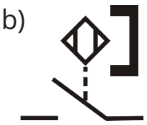
These questions are designed to be a useful aid to revision.
Allow 25 minutes to answer them and then check your answers with those given on page 21.
For questions 1 to 6, choose the correct answer (a, b or c).

1. Electrically operated pneumatic valves are operated by a:
a) solenoid b) lever c) permanent magnet

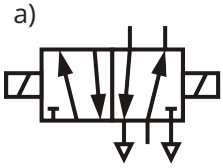
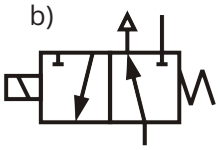
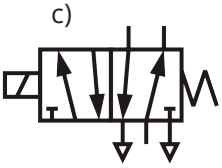
2. Which is the correct description of a 'normally-open' push switch, connected in a circuit?
a) It has no cover on it.
b) It has a very low resistance when pressed.
c) it has a high voltage across it when pressed, and a low voltage when not pressed.

3. What kind of switch is actuated by the magnetic piston ring of a cylinder?
a) reed switch b) push switch c) toggle switch

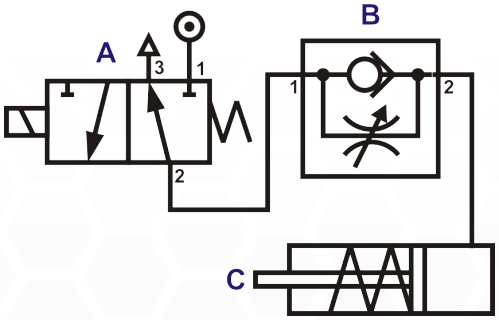
4. Which is the correct symbol for a normally open micro switch?

a) 
b) 
c) 

5. Which is the correct symbol for a solenoid operated, spring return 5/2 control valve?

a) 
b) 
c) 

6. Which statement is true for the pneumatic circuit below?
a) Port 3 on valve A is an exhaust port.
b) Flow control valve B is connected the wrong way round to control the flow of air into cylinder C.
c) When valve A is actuated, cylinder C will retract.



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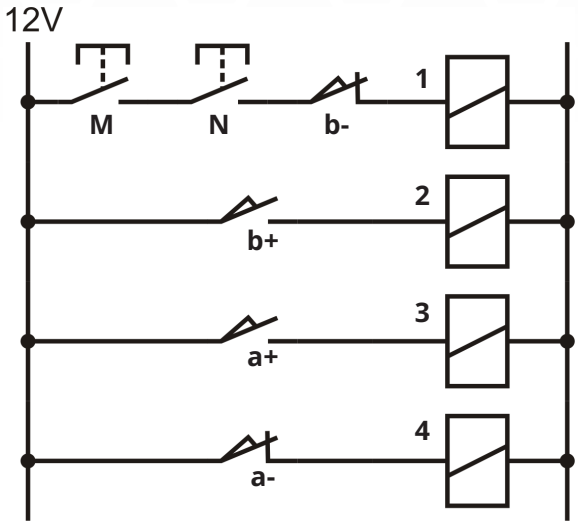
REVISION

Revision Questions

Look at the ladder diagram opposite.



a) Which of the following statements is NOT true:

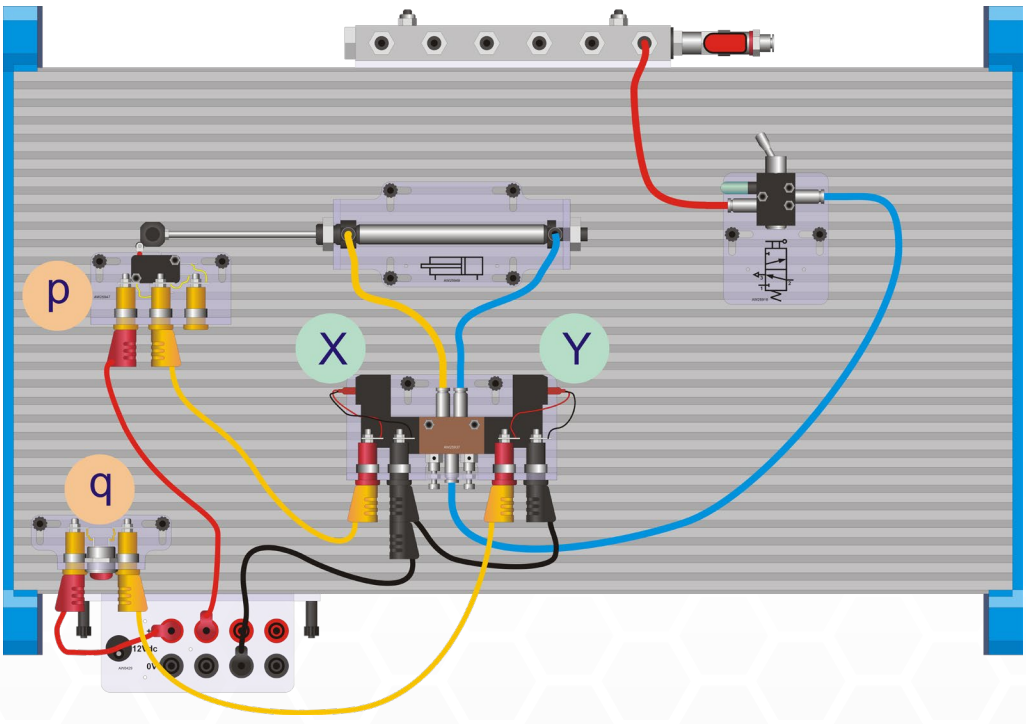
(i) The sequence repeats as long as both switches **M** and **N** are kept closed.
(ii) Switches **M** and **N** are connected in a logic AND configuration.
(iii) The system contains two push switches and four reed switches.

The system is piped so that:

- Solenoid 1 extends cylinder A.
- Solenoid 2 retracts cylinder A
- Solenoid 3 extends cylinder B
- Solenoid 4 retracts cylinder B.

What sequence will be produced by implementing the ladder diagram?

8. For the system shown below, draw
a) the **pneumatic circuit** diagram;
b) the **ladder diagram**, using the labels p, q, X and Y correctly.



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Design Scenarios

Design pneumatic systems to satisfy the requirements set out in the following three letters.
For each, provide a pneumatic circuit diagram and a ladder diagram, like those in the worksheets, together with a description of how the system works.

SpeedRail UK

Internal memo

From: Customer Relations department
To: Design department

As you know, carriage doors on a train are operated by pneumatic cylinders. At present, all doors open every time the train stops at a station.

We have received complaints from passengers that this makes carriages very cold and draughty in winter. They find it especially annoying when only one or two passengers actually get on or off.

Can you please design a new system which allows each door to be opened separately by passengers either from inside or outside the carriage? This will mean that only those doors that are needed will be opened.

Funland resorts

Dear Designer

We are updating the shooting gallery in our amusement arcade, and fitting it out with a new range of targets, with more modern themes.

We would like to feature some 'pop-up' moving targets in the new gallery.

There is a supply of compressed air in the arcade, and so we would like to use an electro-pneumatic system to move the targets up and down.

Please send us suggestions as to how this may be done.

Yours faithfully,

I. Greaves

Funland resorts

Dear Designer

Thank you for the designs you supplied for our new shooting gallery. I wonder if you could also help with our House of Horrors revamp.

This contains several moving waxworks, operated by electro-pneumatic systems. For example, we have Dracula rising from his coffin, 'the killer shark' and many more.

I recently had the idea for a French Revolution exhibit, with a working guillotine, but I need advice on how to design the operating system. The guillotine blade and victim's head will be operated by pneumatic cylinders.

The sequence is:

- lights are off;
- switch operates to turn on lights;
- blade comes down;
- victims head comes off;
- lights go out;
- blade and head return to original position;
- system ready for next performance.

I think this could be a valuable addition to the House of Horrors, and look forward to receiving your designs for the exhibit as soon as possible.

Yours faithfully,

I. Greaves

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ELECTRO-PNEUMATICS

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