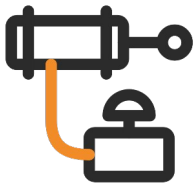
Name: _____ Class: _____

S3 Engineering Science

Booklet 6: Pneumatics



Success Criteria

Lesson	I can …	✓
1 Single-Acting Cylinder	1.1 **follow** the 5 **safety** rules 1.2 **build** and **test** a push-button circuit 1.3 **explain** where the air goes	☐ ☐ ☐
2 Actuators and Valves	2.1 **build** and **test** a lever valve circuit 2.2 **name** the parts of a valve **symbol** 2.3 **draw** a circuit full size	☐ ☐ ☐
3 Uni-directional Restrictor	3.1 **build** and **test** a circuit with a **uni-directional restrictor** 3.2 **explain** how it slows the air one way 3.3 **draw** its symbol the right way round	☐ ☐ ☐
4 Double-Acting Cylinder	4.1 **name** a single-acting and a **double-acting** cylinder 4.2 **simulate** and **build** a double-acting circuit 4.3 **describe** the **outstroke** and the **instroke**	☐ ☐ ☐
5 Fault-Finding	5.1 **find** a fault by **checking in order** 5.2 **describe** a fault, its **cause** and its **fix** 5.3 **hide** a fault safely, with the **air off**	☐ ☐ ☐
6 Force, Pressure and Area	6.1 **use** P = F/A to find a **pressure** 6.2 **find** a **force** or an **area** from P = F/A	☐ ☐
7 OR Control	7.1 **build** and **test** an **OR** circuit 7.2 **explain** how a **shuttle valve** works 7.3 **name** the **tee piece** and the **junction dot**	☐ ☐ ☐
8 AND Control	8.1 **build** and **test** an **AND** circuit 8.2 **explain** where the air stops in AND 8.3 **choose** OR or AND for a job	☐ ☐ ☐
9 Design and Evaluation	9.1 **design** a circuit from a **brief** 9.2 **simulate** and **build** my design 9.3 **test** it against a **specification**	☐ ☐ ☐
10 Review	10.1 **name** every pneumatic **symbol** we have used 10.2 **use** P = F/A 10.3 **describe** what a circuit does	☐ ☐ ☐

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Lesson 1: Single-Acting Cylinder

Learning intention: Use air safely, then build and explain a single-acting cylinder circuit.

Success criteria:

1.1 I can **follow** the 5 **safety** rules ☐

1.2 I can **build** and **test** a push-button circuit ☐

1.3 I can **explain** where the air goes ☐

The 5 safety rules

1 _____ on when you build and when you test.

2 Regulator at _____ while you build or change a circuit.

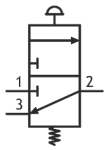
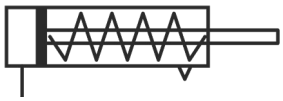
3 Never point _____ at anyone. Tube ends point down.

4 Hear a _____? Regulator to 0 at once.

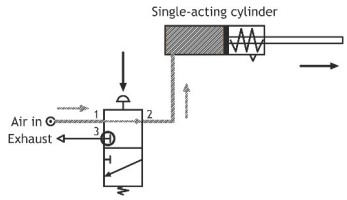
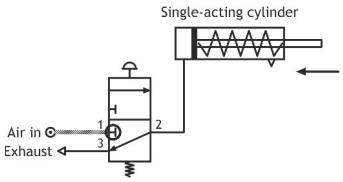
5 Fingers clear of the piston _____.

Test at _____ bar: inner numbers.

Meet the parts

	
3/2 valve: _____ ports, _____ states **Button:** push it to change _____ **Spring:** pushes it _____	**Single-acting:** air pushes _____ way **Outstroke:** air pushes the rod _____ **Instroke:** a _____ pushes it in

Where the air goes (hatched = air)

	
Push the button: both boxes slide _____. Port _____ is now blocked. Air flows in port _____, out of port _____. The rod moves _____: the outstroke.	Let go: the _____ pushes the boxes up. Port _____ is now blocked. Air leaves: in port 2, out of port _____. The rod moves _____: the instroke.

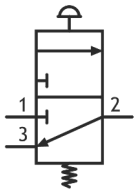
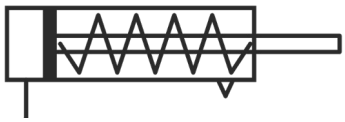
My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Name** each part. (2)

	
A	**B**

A _____ B _____

2 **Complete** the safety rules. (2)

While you build, the regulator is at _____. We test between _____ and _____ bar.

3 **Complete** the sentences about **pressing** the button. (2)

The rod goes _____. Air flows in port _____ and out of port _____.

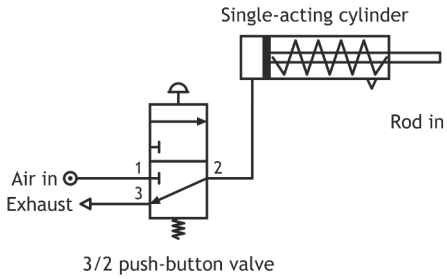
4 **Complete** the sentences about **letting go**. (2)

The _____ pushes the rod in. Air leaves through port _____.

5 **Complete** the sentence. (1)

A 3/2 valve has _____ ports and _____ states.

6 **Describe** what happens when the button is **pressed**, then **released**. **Challenge: Describe it** (2)



3/2 push-button valve

When the button is pressed, air goes

When the button is released,

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Lesson 2: Actuators and Valves

Learning intention: Build a lever-actuated valve circuit, read the valve symbol and draw it full size.

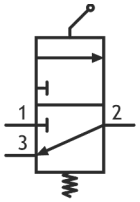
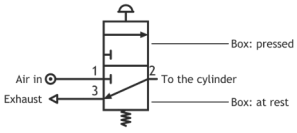
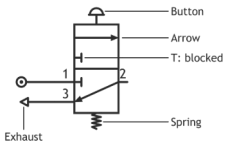
Success criteria:

2.1 I can **build** and **test** a lever valve circuit ☐

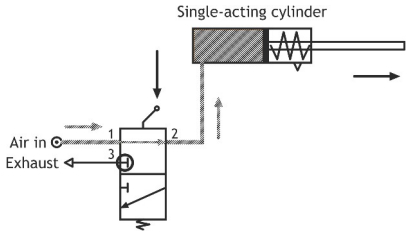
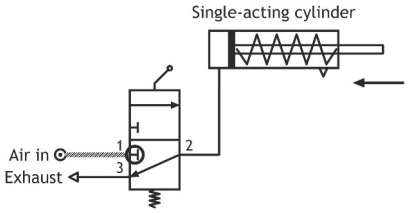
2.2 I can **name** the parts of a valve **symbol** ☐

2.3 I can **draw** a circuit full size ☐

Meet the parts

		
3/2 valve: _____ ports, _____ states **Lever:** move it to change _____ **Spring:** pushes it _____	**Box:** one _____ of the valve **2 boxes:** _____ and at _____ **Ports:** 1 _____, 2 _____, 3 _____	**Arrow:** the _____ the air takes **T:** that port is _____ **Spring:** pushes the valve _____

Where the air goes (hatched = air)

	
Move the lever: both boxes slide _____. Port _____ is now blocked. Air flows in port _____, out of port _____. The rod moves _____: the outstroke.	Let go: the _____ pushes the boxes up. Port _____ is now blocked. Air leaves: in port 2, out of port _____. The rod moves _____: the instroke.

My notes:

Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Complete** the sentences about the valve **symbol**. (2)

Each box is one _____ of the valve.

Port _____ is air in, port _____ is out to the cylinder and port _____ is the exhaust.

2 **Complete** the sentences. (2)

The arrow shows the _____ the air takes. A T shows the port is _____.

3 **Complete** the sentences about the circuit you built. (2)

Move the lever: the rod goes _____. Let go: the _____ pushes the valve back.

4 **Complete** the sentence. (1)

Today's valve is moved by a _____; Lesson 1's by a _____.

5 **Complete** the sentence to **name** the valve. (1)

A valve with 3 ports and 2 states is a _____ valve.

6 **Draw** the symbol for a 3/2 lever valve with spring return. **Number** the ports. **Challenge:** **Draw it** (3)

Space for working and answer

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Lesson 3: Uni-directional Restrictor

Learning intention: Build a circuit that slows the rod, and explain how a uni-directional restrictor does it.

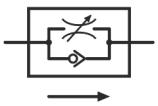
Success criteria:

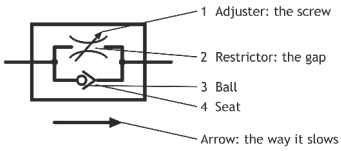
3.1 I can **build** and **test** a circuit with a **uni-directional restrictor** ☐

3.2 I can **explain** how it slows the air one way ☐

3.3 I can **draw** its symbol the right way round ☐

Meet the parts





Uni-directional restrictor: _____ the air one way

Screw: sets how _____

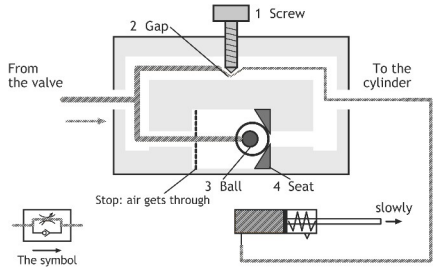
Arrow: the _____ it slows

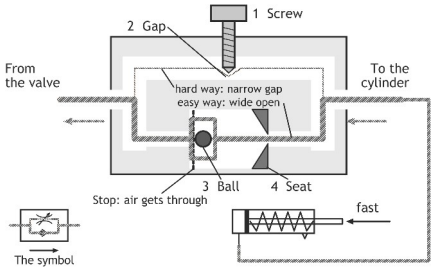
1 Screw: sets the _____

2 Gap: _____ the air

3, 4 Ball, seat: _____ way only

Inside the valve (hatched = air)





Air arrives from the valve.

It pushes the ball onto its _____: shut.

It squeezes through the _____: slow.

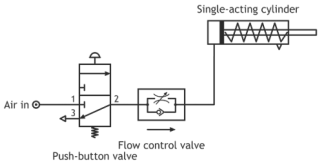
Screw in: smaller gap, _____.

Air comes back from the cylinder.

It pushes the ball _____ its seat.

Most air takes the easy way: _____.

The circuit you built



Input: push-button valve

Control: flow control valve

Arrow: _____ the cylinder

My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Complete** the sentence to **name** the valve. (1)

The valve that slows the rod is a _____.

2 **Complete** the sentences about the circuit you built. (2)

Arrow to the cylinder: the rod goes out _____ and comes back _____.

3 **Complete** the sentence. (1)

Turning the screw in makes the _____ smaller, so it _____ the air more.

4 **Complete** the sentence to **explain** why the rod comes back fast. (2)

Air coming back pushes the ball _____ its seat, so the air flows _____.

5 **Complete** the sentence. (1)

To slow the outstroke, the arrow points _____.

6 The speed of the piston movement needs to be slowed down. **Draw** the symbol for a uni-directional restrictor to slow the air flow in the direction shown. **Challenge: Exam** (2)



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Lesson 4: Double-Acting Cylinder

Learning intention: Use a double-acting cylinder, build it, and find out what pushes the rod back.

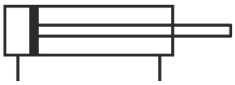
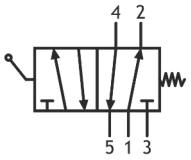
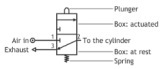
Success criteria:

4.1 I can **name** a single-acting and a **double-acting** cylinder ☐

4.2 I can **simulate** and **build** a double-acting circuit ☐

4.3 I can **describe** the **outstroke** and the **instroke** ☐

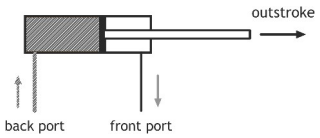
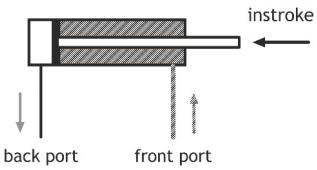
Meet the parts

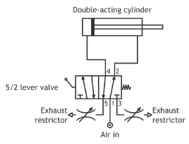
		
Double-acting: a new cylinder **Ports:** _____ **Spring:** _____ inside	**5/2 lever valve:** sends the _____ **Lever:** you _____ it **Spring:** pushes the valve _____	**Plunger:** a short _____ on the valve **Pressed by:** a _____ part

Single-acting: _____ port and a _____

Double-acting: _____ ports: air both ways

Where the air goes (hatched = air)

	
Air goes in at the _____ port. The back fills; the front air _____. The rod moves out: the _____.	Air goes in at the _____ port. The front fills; the back air _____. The rod moves in: the _____.



Push the lever: air goes 1 to _____, to the _____.

Let go: the _____. Air goes 1 to _____, to the _____.

Push the lever: air to the _____: _____

Let go: air to the _____: _____

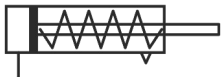
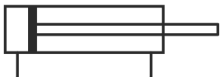
My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Name** cylinders **A** and **B**. (2)

	
A	**B**

Cylinder A is _____.

Cylinder B is _____.

2 **Complete** the sentences about a **double-acting** cylinder. (2)

It has _____ ports.

_____ pushes the rod back in.

3 **Complete** the sentences. **Use outstroke** or **instroke**. (2)

The rod moving out is the _____.

The rod moving in is the _____.

4 **Complete** the sentences to **explain** why a **heavy** load needs a double-acting cylinder. (2)

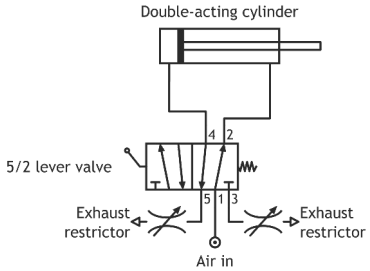
A _____ is too weak to push a heavy load back.

In a double-acting cylinder, _____ pushes the rod back in.

5 **Complete** the sentence to **name** the actuator. (1)

A short rod on a valve, pressed in by a moving part, is a _____.

6 **Describe** what happens when the lever is **pushed**, then **let go**. **Challenge: Describe it** (2)



When the lever is pushed, air goes

When the lever is let go,

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Lesson 5: Fault-Finding

Learning intention: Find a fault safely by checking in order, then describe it.

Success criteria:

5.1 I can **find** a fault by **checking in order** ☐

5.2 I can **describe** a fault, its **cause** and its **fix** ☐

5.3 I can **hide** a fault safely, with the **air off** ☐

Check in order

Check: yes, go on down	**If no: fix it**
1 Regulator at _____? Hands clear?	Stop. Do this first.
2 Every tube pushed in _____?	Push it in.
3 Every tube on the right _____?	Move it.
4 Both _____ open?	Open it.
5 Every part _____ down tight?	Tighten the bolt.
6 _____ checks. Does it work?	Air off. Back to 1.

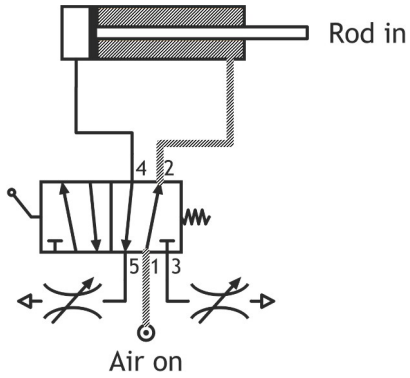
The only faults you may hide

Swap 4 and 2: a _____

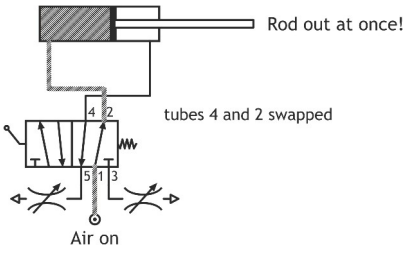
Restrictor in: a _____

Loose bolt: a _____

Why the air must be off (hatched = air)



Right tubes, air on: the _____ fills. The rod stays _____.



Tubes 4 and 2 swapped, air on: the _____ fills. The rod shoots _____ at once.

My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Complete** the sentence about **check 1**. (1)

Before you look for a fault, turn the regulator to _____.

2 Tubes **4** and **2** are swapped. **Complete** the sentence to **describe** what the rod does. (2)

The rod goes _____ as soon as the air is turned _____.

3 **Complete** the sentence to **explain** why the air must be off when you look for a fault. (2)

The rod can move _____ and could trap your _____.

4 The rod moves very slowly. **Complete** the sentences to **describe** the cause and the fix. (2)

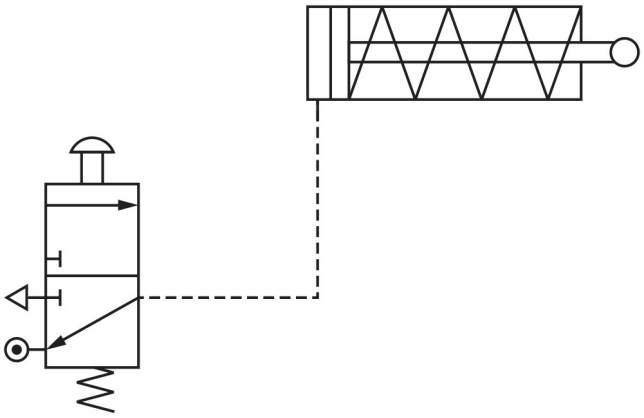
Cause: an exhaust restrictor is screwed right _____.

Fix: _____ the restrictor.

5 **Complete** the sentence about circuit drawings. (1)

A main pipe is drawn as a _____ line.

6 **Describe** two errors that were made in this circuit diagram. **Challenge: Exam** (2)



Error 1:

Error 2:

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Lesson 6: Force, Pressure and Area

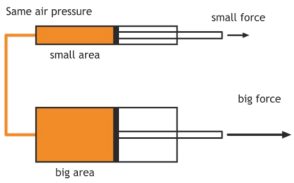
Learning intention: Use pressure, force and area to work out what a cylinder can do.

Success criteria:

6.1 I can **use** P = F/A to find a **pressure** ☐

6.2 I can **find** a **force** or an **area** from P = F/A ☐

Why a bigger cylinder pushes harder



Same pressure: the same push on every _____ of piston

Bigger area: more mm² for the air to _____ on

So: a bigger _____

Pressure, force and area

$$P = F / A$$

P = pressure, in _____

F = force, in _____

A = area, in _____

Our gauge: 1 bar = 0.1 N mm^{-2}

Worked example

A piston has an area of 250 mm². It outstrokes with a force of 40 N. **Calculate** the air pressure supplied.

F = 40 N A = 250 mm² P = ?

P = F / A

P = 40 / 250

P = 0.16 N mm^{-2}

My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Complete** the sentence. (2)

A _____ piston has more _____, so it pushes harder.

2 A piston has an area of 300 mm^2. It outstrokes with a force of 60 N. **Calculate** the air pressure supplied. (2)

P = F/A, P =

P =

3 The air pressure is 0.2 N mm^{-2} and the piston area is 400 mm^2. **Calculate** the outstroking force. (3)

P = F/A, 0.2 =

F =

F =

4 A piston outstrokes with a force of 100 N when the air pressure is 0.25 N mm^{-2}. **Calculate** the piston area. (3)

P = F/A, 0.25 =

A =

A =

5 **Complete** the units. (1)

P: _____ F: _____ A: _____

6 The piston in the cylinder has a cross sectional area of 420 mm^2 and instrokes with a force of 65 N. **Calculate** the air pressure supplied to instroke the piston. **Challenge: Exam** (2)

P = F/A, P =

P =

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Lesson 7: OR Control

Learning intention: Build an OR circuit and explain how the shuttle valve lets either button work the cylinder.

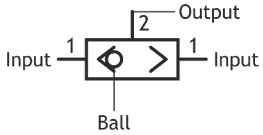
Success criteria:

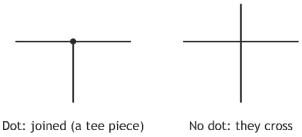
7.1 I can **build** and **test** an **OR** circuit ☐

7.2 I can **explain** how a **shuttle valve** works ☐

7.3 I can **name** the **tee piece** and the **junction dot** ☐

Meet the parts

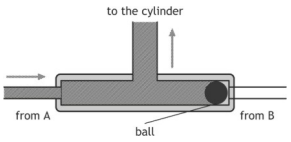


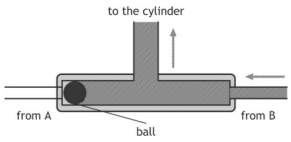


Shuttle valve: _____ inputs, _____ output
Inputs: both numbered _____
Output: port _____

T-connector: joins _____ pipes
Symbol: a _____ where pipes join
No dot: they _____: not joined

Inside the shuttle valve (hatched = air)

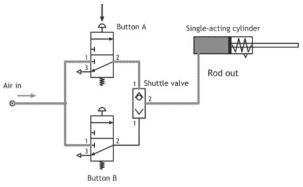


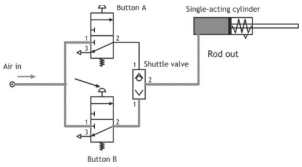


Air from A pushes the ball _____. It _____ B's side: air goes to the cylinder.

Air from B pushes the ball _____. Air still goes to the cylinder.

Follow the air





Press A: air goes through A and the _____. The rod goes _____.

Press B: air goes through B and the shuttle. The rod goes _____.

OR: valve A _____ valve B works it

Pipes: side by side, into a _____ valve

Where: a door: inside OR outside button

My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Complete** the sentence to **name** the valve. (1)

A valve with two inputs and one output is a _____ valve.

2 **Complete** the sentences about the **OR** circuit you built. (2)

Press A only: the rod goes _____. Press B only: the rod goes _____.

Press neither: the rod stays _____.

3 **Complete** the sentence. (1)

In OR control, button A _____ button B makes the rod go out.

4 **Complete** the sentences about joining pipes. (2)

The part that joins three pipes is a _____.

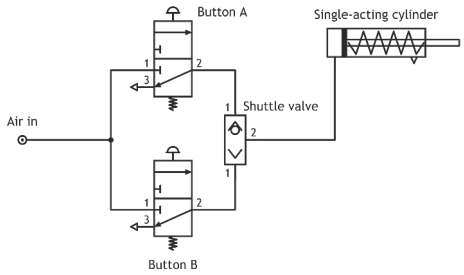
On a circuit diagram, a dot shows the pipes are _____.

5 **Complete** the sentence to **explain** what the ball in a shuttle valve does. (2)

The ball blocks the side with no _____, so air cannot escape out of the other valve's _____.

6 **Describe** what happens when button A is **pressed**, then **released**. (2)

Challenge: Describe it



When button A is pressed, air goes

When button A is released,

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Lesson 8: AND Control

Learning intention: Build an AND circuit, explain where the air stops, and choose OR or AND for a job.

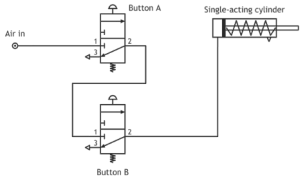
Success criteria:

8.1 I can **build** and **test** an **AND** circuit ☐

8.2 I can **explain** where the air stops in AND ☐

8.3 I can **choose** OR or AND for a job ☐

Meet the circuit

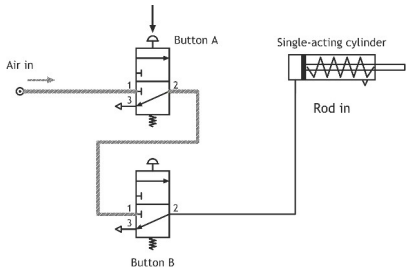


Parts: two _____ valves

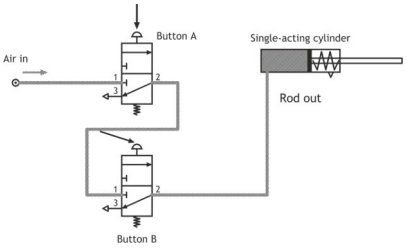
New: how they are _____

Out of A: into _____, then the cylinder

Follow the air (hatched = air)



Press A only: air goes through A and _____ at B. Rod _____.



Press A and B: air goes through A, then B. The rod goes _____.

AND control

AND: valve A AND valve B, _____ on

Pipes: in a _____: out of A, into B

Where: a press: _____ safety

My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Complete** the sentence. (1)

In AND control, button A _____ button B must both be pressed.

2 Only button A is pressed. **Complete** the sentence to **describe** what happens. (2)

The air stops at button _____, so the rod stays _____.

3 **Complete** the sentence about the piping. (1)

For AND, the valves are piped in a _____: out of A, into B.

4 **Complete** the sentence to **explain** why a press uses AND. (2)

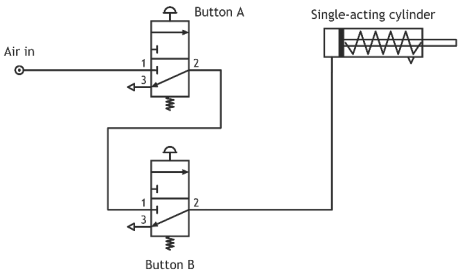
Both _____ are on buttons, away from the _____, so they cannot be trapped.

5 **Choose** OR or AND for each job. (2)

A door opens from an inside or an outside button: _____

A press needs both hands on buttons: _____

6 **Describe** what happens when only A is pressed, then when A and B are pressed. **Challenge: Describe it** (2)



When only A is pressed, air

When A and B are pressed,

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Lesson 9: Design and Evaluation

Learning intention: Design, simulate, build and test a circuit for a brief, then evaluate it.

Success criteria:

9.1 I can **design** a circuit from a **brief** ☐

9.2 I can **simulate** and **build** my design ☐

9.3 I can **test** it against a **specification** ☐

The brief

The job: a press stamps a logo on a key ring

The danger: a _____ under the press

The idea: one _____ for each hand

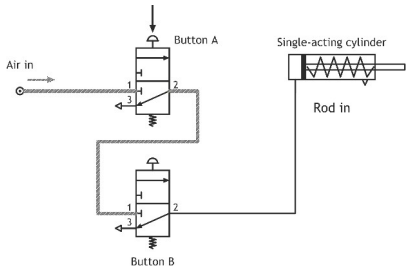
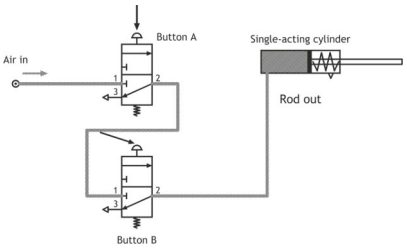
The specification

i Both buttons pressed: the press comes down.

ii One button only: the press does not move.

iii Either button let go: the press goes back up.

One solution (hatched = air)

	
One button: the air _____ at B. The press stays up.	Both buttons: air through A, then B. The press comes _____.

Evaluate it

Say: which points were _____

Improve: one _____ to the design

Justify: _____ it is better

My notes:

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

Brief: a press stamps a logo on a key ring. It must only come down when the worker presses two buttons, one with each hand.

Specification: i Both buttons pressed: the press comes down. ii One button only: the press does not move. iii Either button let go: the press goes back up.

1 **Choose** the control the press needs. (1)

The press needs _____ control.

2 **Complete** the parts list. (2)

Two _____ valves and one _____ cylinder.

3 **Draw** your circuit. (3)

Space for working and answer

4 **Test** your design. Tick met or not met for each point. (3)

Specification point	Met	Not met
i Both pressed: comes down		
ii One only: does not move		
iii Let go: goes back up		

5 **Describe** one improvement to your design and **justify** it. (2)

One improvement is

This is better because

6 **Explain** why AND makes the press safe. **Challenge: Explain it** (2)

The press only comes down when _____ buttons are pressed, so both _____ are away from the press.

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Lesson 10: Review

Learning intention: Get ready for the test by remembering every lesson.

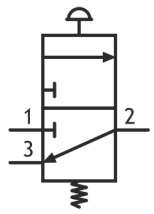
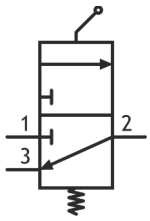
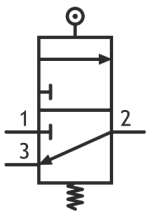
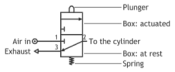
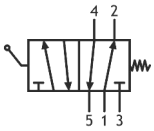
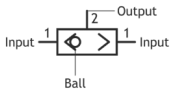
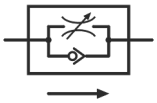
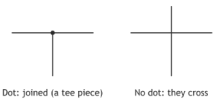
Success criteria:

10.1 I can **name** every pneumatic **symbol** we have used ☐

10.2 I can **use** P = F/A ☐

10.3 I can **describe** what a circuit does ☐

Name the symbol

			
1 _____	2 _____	3 _____	4 _____
			
5 _____	6 _____	7 _____	8 _____
			
9 _____	10 _____	11 _____	12 _____

Remember

P = F / A. P in _____, F in _____, A in _____.

OR: pipes side by side, into a _____ valve.

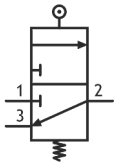
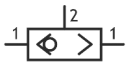
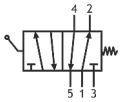
AND: pipes in a _____, out of A into B.

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Review Questions

Answer Questions 1 to 5. Finished? Try the **Challenge**.

1 **Name** each symbol. (4)

			
A	**B**	**C**	**D**

A _____ B _____

C _____ D _____

2 **Complete** the sentences. (2)

Rod moving out: _____. Rod moving in: _____.

3 A piston has an area of 400 mm². It outstrokes with a force of 60 N. **Calculate** the air pressure supplied. (2)

P = F/A, P =

4 **Choose** OR or AND for each job. (2)

Door, either button: _____ Press, both hands: _____

5 **Complete** the sentences about fault-finding. (2)

Check 1: turn the regulator to _____.

Tubes 4 and 2 swapped: the rod goes _____ as soon as the air is on.

6 A piston outstrokes with a force of 100 N when the air pressure is 0.25 N mm^{-2}. **Calculate** the piston area. **Challenge: Calculate** (3)

P = F/A, 0.25 =

A =

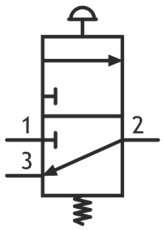
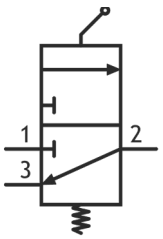
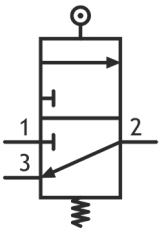
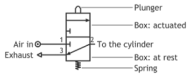
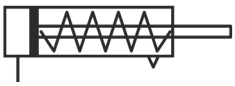
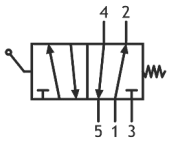
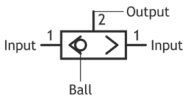
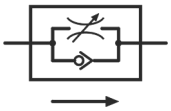
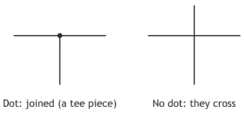
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Knowledge Organiser: Key Words

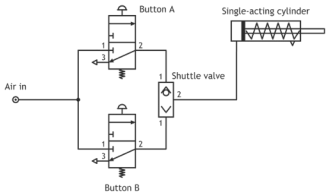
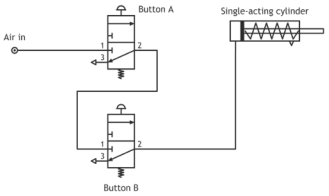
Pneumatics	using compressed air to make things move
Compressed air	air squashed into a small space
Regulator	sets the air pressure: 0 to build, 1 to 2 bar to test
Actuator	what changes a valve's state: button, lever, roller or plunger
Port	where a pipe joins: 1 air in, 2 or 4 out, 3 or 5 exhaust
State	one position of a valve: one box on the symbol
3/2 valve	3 ports, 2 states
5/2 valve	5 ports, 2 states: sends air to either end of a cylinder
Spring return	a spring pushes the valve back when you let go
Single-acting cylinder	air pushes the rod out; a spring pushes it in
Double-acting cylinder	two ports, no spring: air pushes the rod out and in
Outstroke / instroke	the rod moving out / in
Uni-directional restrictor	slows the air one way only: the way of its arrow
Exhaust	where used air leaves the circuit
Shuttle valve	two inputs, one output: used for OR
T-connector	joins three pipes; a dot on a circuit diagram
OR control	either valve works the cylinder
AND control	both valves must be on
Pressure	force on each mm^2: $P = F / A$, in $N\ mm^{-2}$
Brief	the problem a design must solve
Specification	the list of things a design must do; each one can be tested
Evaluate	say which points were met, one improvement and why

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Knowledge Organiser: Symbols

		
3/2 push-button valve	**3/2 lever valve**	**3/2 roller valve**
		
Plunger	**Single-acting cylinder**	**Double-acting cylinder**
		
5/2 lever valve	**Shuttle valve**	**Uni-directional restrictor**
		
Air supply	**Exhaust**	**Joined; not joined**

OR and AND

	
OR: side by side, into a shuttle valve	**AND:** in a line, out of A into B

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Knowledge Organiser: Summary

1 Single-Acting Cylinder	Goggles on; regulator at 0 to build; test at 1 to 2 bar. A 3/2 valve has 3 ports and 2 states. Press: air flows 1 to 2 and the rod goes out (outstroke). Let go: air leaves through 3 and the spring pushes the rod in (instroke).
2 Actuators and Valves	An actuator changes the valve's state: button, lever, roller or plunger. Each box is one state; the arrow is the air's path; a T is a blocked port. Ports: 1 in, 2 out, 3 exhaust.
3 Uni-directional Restrictor	A uni-directional restrictor slows the air one way: the way of its arrow. The screw sets the gap. Air coming back pushes the ball off its seat and flows freely. Arrow to the cylinder: slow out, fast in.
4 Double-Acting Cylinder	A double-acting cylinder has two ports and no spring: air pushes the rod out and back. A 5/2 valve sends the air: push the lever, air to the back, rod out; let go, air to the front, rod in.
5 Fault-Finding	Check in order, regulator at 0 first: tubes in fully, right ports, restrictors open, parts tight; air on only after the teacher checks. Tubes 4 and 2 swapped: the rod shoots out.
6 Force, Pressure and Area	$P = F / A$. Pressure in N mm^{-2}, force in N, area in mm^2. The same pressure on a bigger area gives a bigger force. 1 bar = 0.1 N mm^{-2}.
7 OR Control	OR: either valve works the cylinder. The valves sit side by side, into a shuttle valve; its ball blocks the side with no air. A dot shows pipes joined.
8 AND Control	AND: both valves must be on. The valves are in a line: out of A, into B. Used for a two-hand safety press.
9 Design and Evaluation	Brief, then specification, then design, simulate and build. Test each point: met or not met. Evaluate: one improvement and why it is better.

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