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Department of Mechanical, Materials & Manufacturing Engineering
Design, Manufacture and Project
MMME 2044

Air Motor Feedback

Professor G E Kirk

Introduction

- The purpose of this lecture is to give feedback on the Air Motor design exercise.
- It describes a process that was followed to arrive at an outcome.
- It is presented in a logical step by step process, but in practice there were many iterations.
- A solution is presented, it is not the only solution and it may not be the best solution.

The Task

What can be deduced from available information

- The motor has three pistons (Tripiston)
- There is a focus on low cost as opposed to power , targeted at 12W
- There is the use of a needle roller bearing FAG NK24/16
- There is significant use of Additive Manufacture

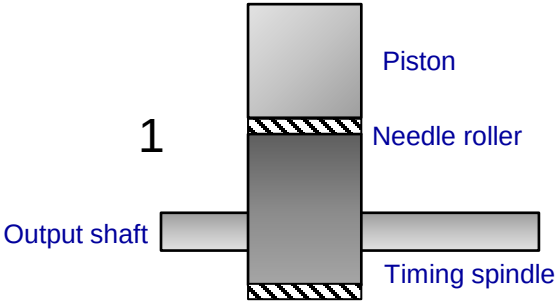
A Statement of Requirements

No	Customer(s)	Requirement	Method of Demonstrating Compliance	Rank
1	Board	The motor shall produce a minimum of 12W at 600 rpm with 60% efficiency	Test	1
2	Board	The configuration shall be the best estimate of Rivale's motor	Observation	1
3	Board	The cost shall be significanty less than the current TP12	Observation	1
4	Board	The unit shall be availble for test June 2023	Test	1
5	Board	The motor shall fit the current test rig	Test	1
6				

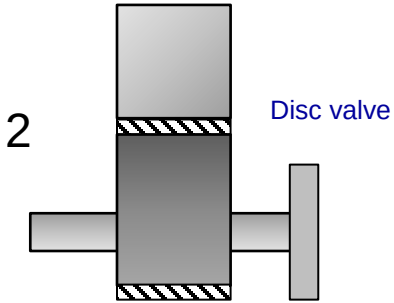
The Morphology Chart

To poduce power using high pressure air							
	Functions/Means	**A**	**B**	**C**	**D**	**E**	**F**
1	**To convert pressure energy to kinetic**	Turbine	In-line reciprocating piston	Axial reciprocating piston	Radial reciprocating piston		
2	**To convert linear motion to rotative**	Crank	Offset circular cam	Lobed cam	Rack and pinion	Scotch Yoke	None
3	**To time air supply and exhaust**	Shaft mounted disc valve	Shaft mounted spindle valve	Camshaft	Electronic	None	
4	**To reduce speed**	Gear train	None				
5	**To regulate inlet / outlet**	Poppett valve	Disc valve	Spindle valve	Reed valve	None	

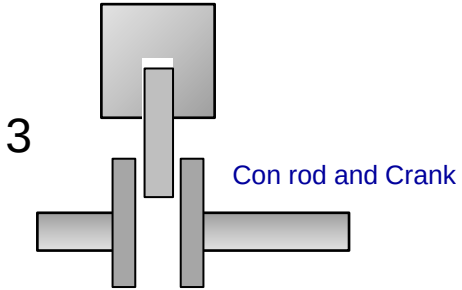
The Options



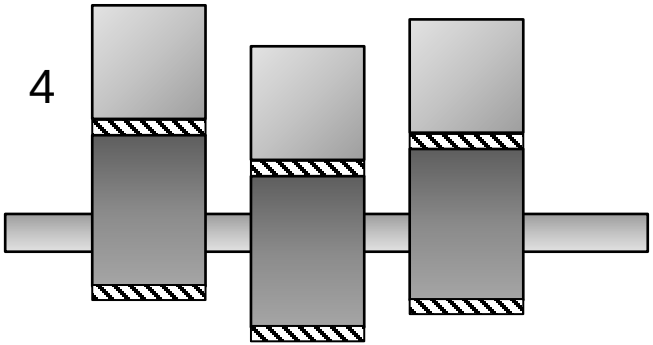
1D. 2B, 3B, 4B, 5C



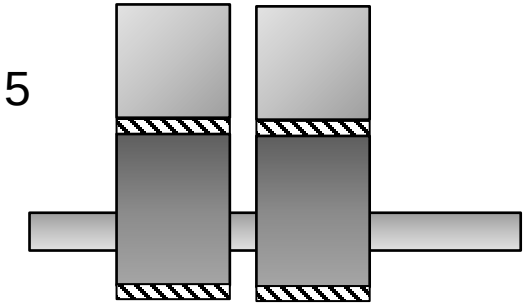
1D. 2B, 3A, 4B, 5C



1D. 2A, 3B, 4B, 5C

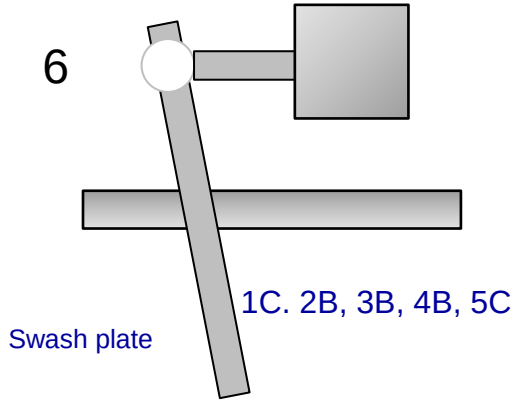


1B. 2B, 3B, 4B, 5C



1D*. 2B, 3B, 4B, 5C

- *Double power*



1C. 2B, 3B, 4B, 5C

Rough Order of Magnitude Calculations (ROM)

- It is useful to establish the physical size of the motor by some ROM calculations.

Nett power	W_n
Efficiency	η
Minimum gross power	W_g
Pressure	P
Speed	w
Torque	T
Force	F
Radius of application of Force	r

$$W = T\omega$$

$$T = \frac{W}{\omega}$$

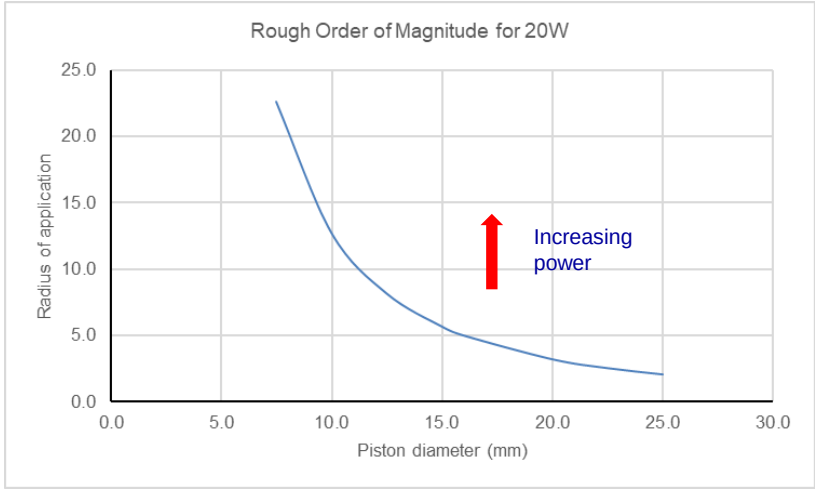
$$T = F.r$$

$$F = \frac{\pi.D^2}{4}.P$$

$$\frac{W}{\omega} = \frac{\pi.D^2}{4}.P.r$$

$$\frac{4W}{\omega.\pi.P} = D^2.r$$

$$r = \frac{4W}{\omega.\pi.P.D^2}$$



For constant D, P and ω then $r \propto c.W$

The Initial Selection

- There are many options in the Morphology Chart so there needs to be a selection of the most likely for further work and elimination the others.
- It is based on engineering judgement which may turn out to be incorrect with further study so it is vital that the rational is recorded in case it has to be revested.

		1	2	3	4	5	6
1	Power 12W 600 rpm η 60%						
2	As Rivale						
3	Cost						
4	Available March 2023						
5	Fit the currenr rig						

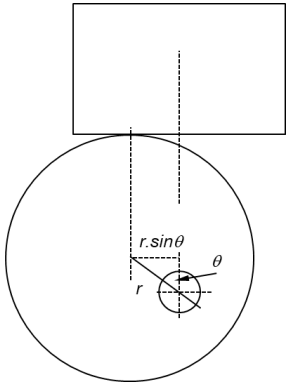
- Option 1 worth pursuing.
- Option 2 is difficult to seal and may take longer to design.
- Option 3 does not incorporate the needle roller bearing but has the potential for for more power so worth a consideration, cost differential with AM is unlikely to be an issue.
- Option 4 Likely to be more expensive, more parts to make ad assemble with
- Option 5 Basically as Option 1 keep in mind if there is a power shortfall.
- Option 6 Technically difficult likely to be more expensive.

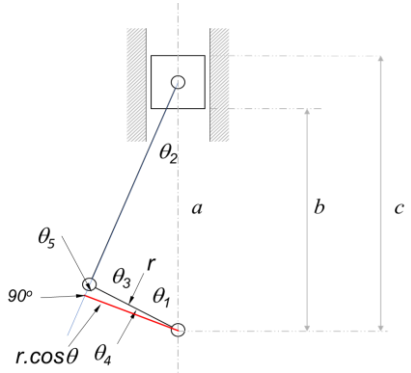
Converting Linear Motion to Rotary

- The radius of application of the piston force is a function
  - of the output shaft angle rotation

  and
  - the offset for the offset cam, *r*

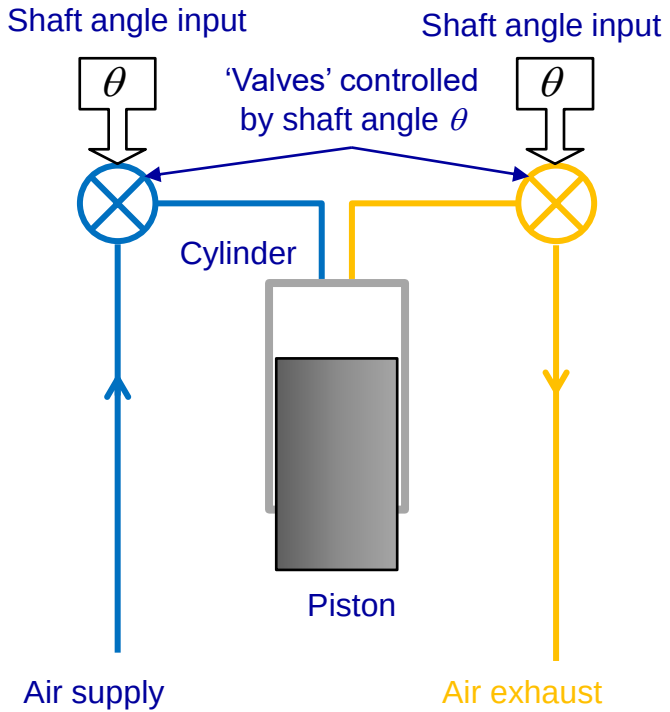
  or
  - the crank throw, *r*
- The crank calculation is slightly more complex but a similar spreadsheet can be constructed.





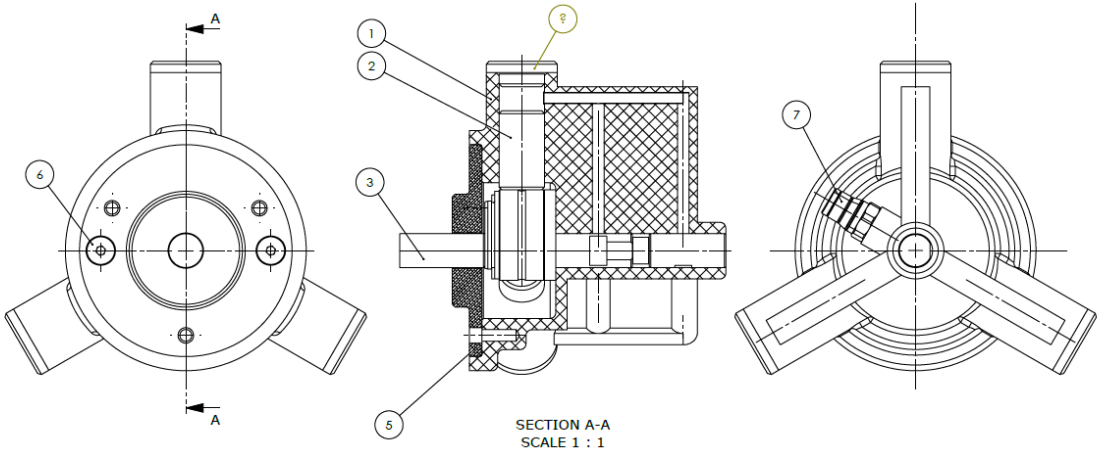
Air Supply and Timing

- Pressurised air needs to be introduced into the cylinder and exhausted at the optimum points of the piston stroke.
- The timing for both is a function of the output shaft angle.
- Each cylinder has to fed and exhausted in turn.
- A spread sheet is a convenient way of modelling the combination of inlet/exhaust timing and the radius of application.



Air Motor – Basic General Arrangement

ITEM	DRAWING NO.	DESCRIPTION (DO NOT SCALE)	MATERIAL	MATERIAL CODE	VENDOR	PART No	QTY.
1	P002	Cylinder Body	PBT				1
2	P005	Piston	1060 Alloy	MJ-B02012	L2 Stores		3
3	A002	Rotor Assembly					1
4	P007	Cylinder Cap	PBT				3
5	P004	Endcap	1060 Alloy	MJ-B02034	L2 Stores		1
6		Csk Skt Head Screw M5 x 16	Steel		L2 Stores	MH-D04017	2
7		Air Connection	B/O		Legris	3601_06_10	1



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TOLERANCE
LINEAR: ± 0.5
ANGULAR: ± 1°

AIR MOTOR ASSEMBLY AM BODY

ALL DIMENSIONS ARE IN MILLIMETRES	ISSUE DATE	REVISION	DRAWN BY	DRAWING NO.
	13/01/2023		Kk	A001
DRAFTING STANDARD	MODULE	SCALE	SIZE	SHEET
BS 8888	MMME 2044	1:1	A3	1 of 2

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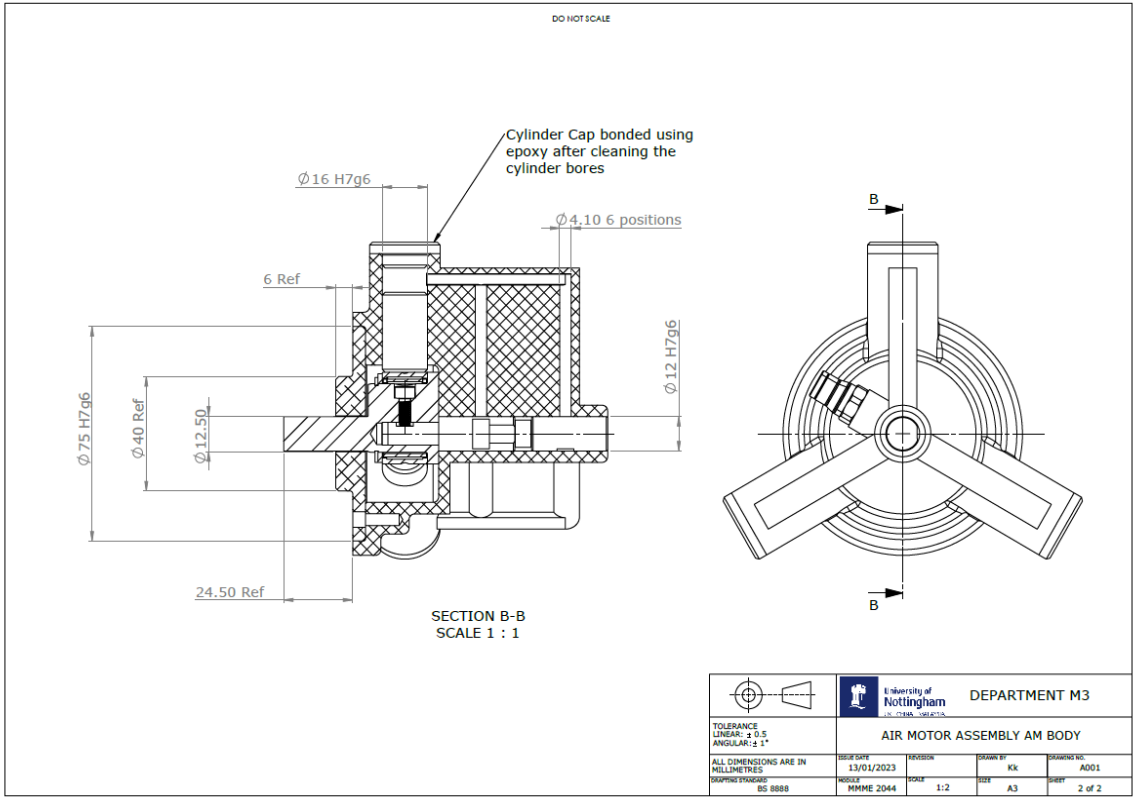
Air Motor – Basic General Arrangement



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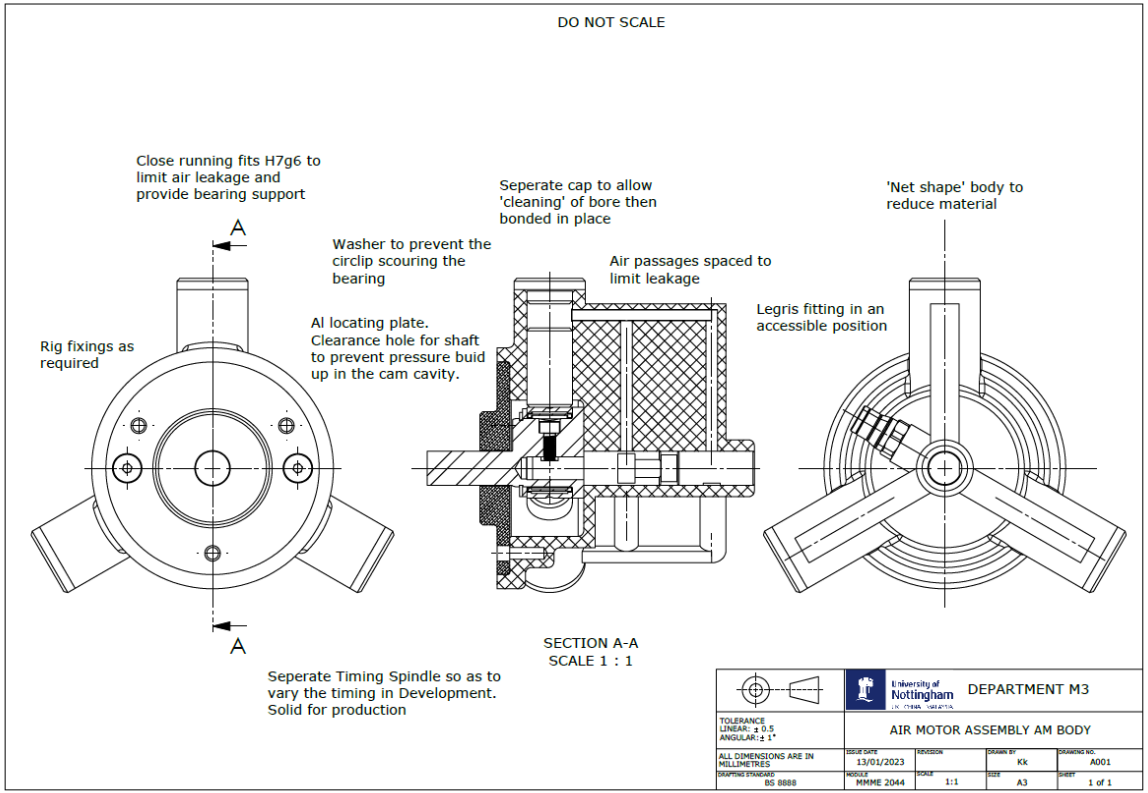
Design Features



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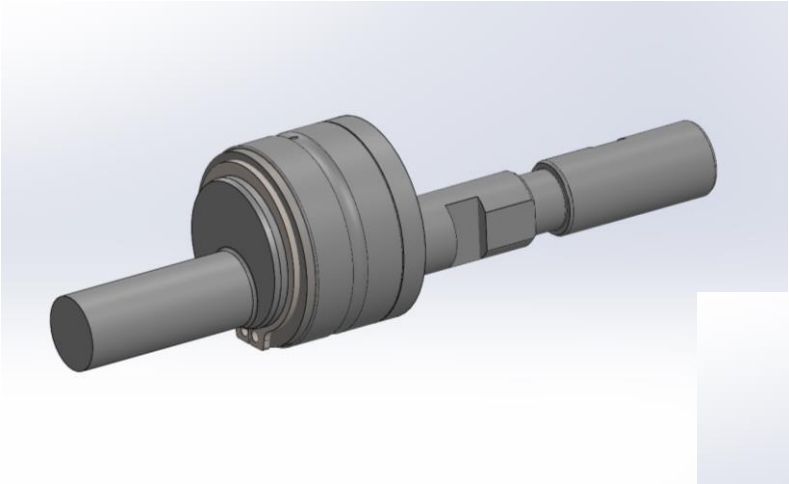
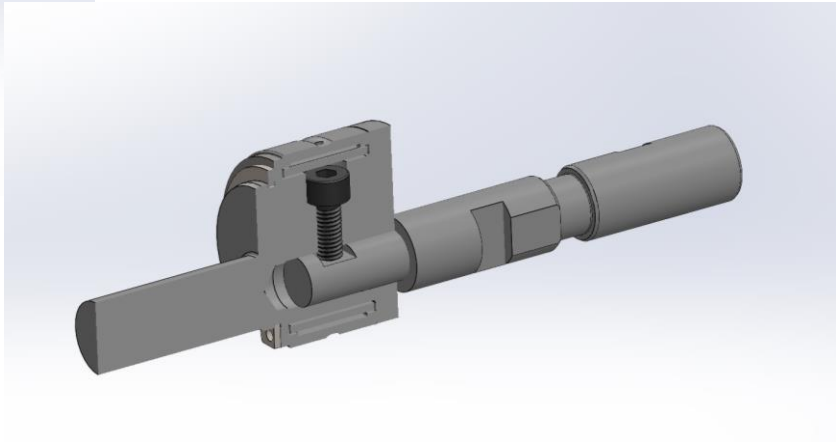
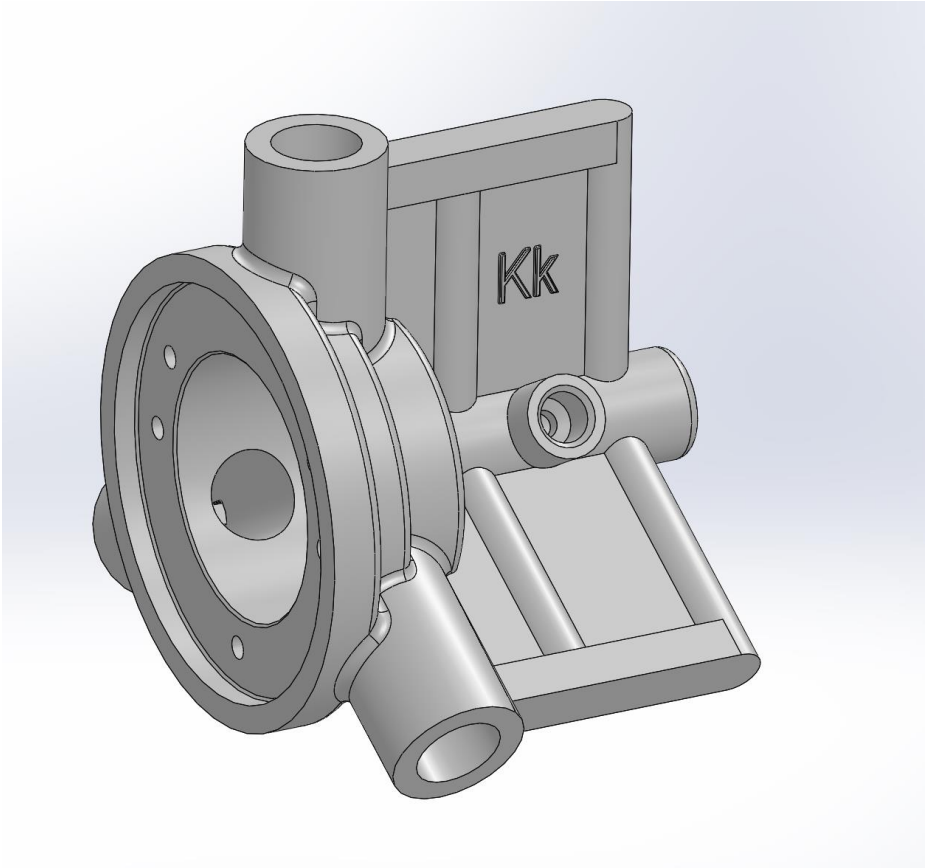
The Rotor Assembly - Basic

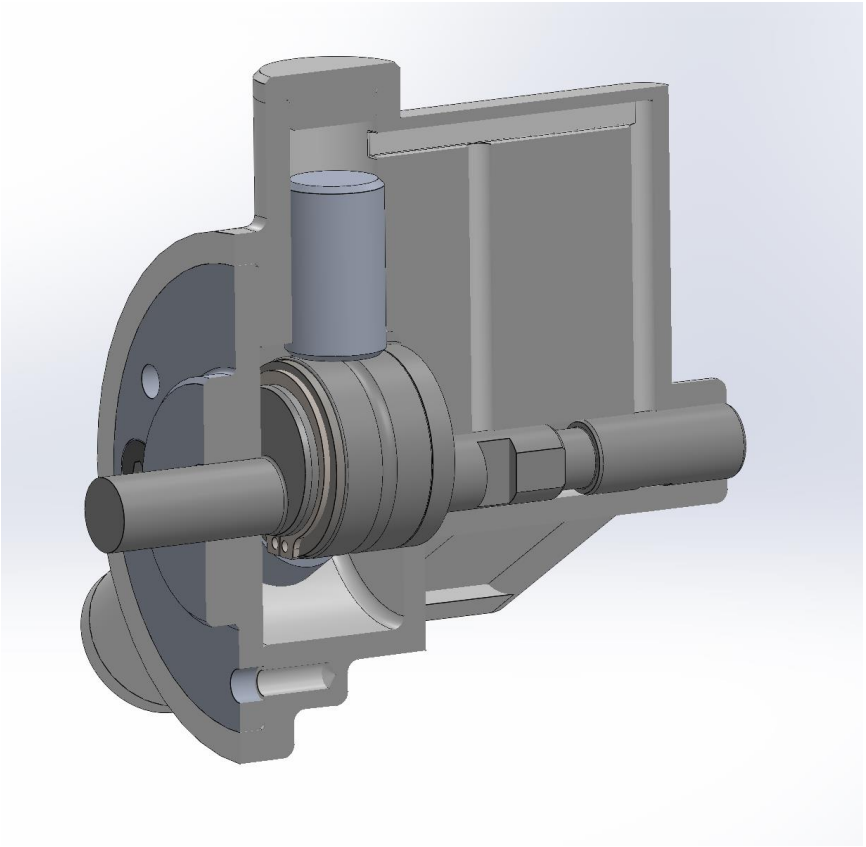




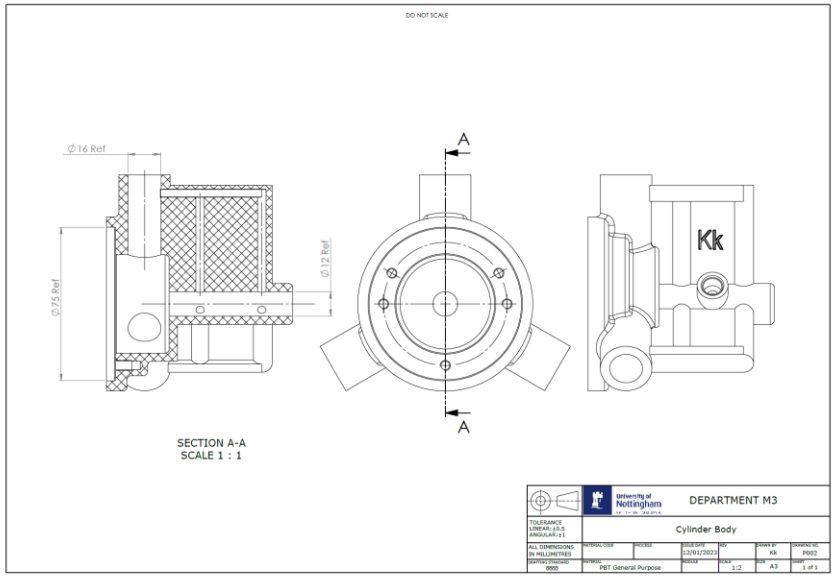
The Cylinder Body



Air Motor - Basic



Detail Drawings



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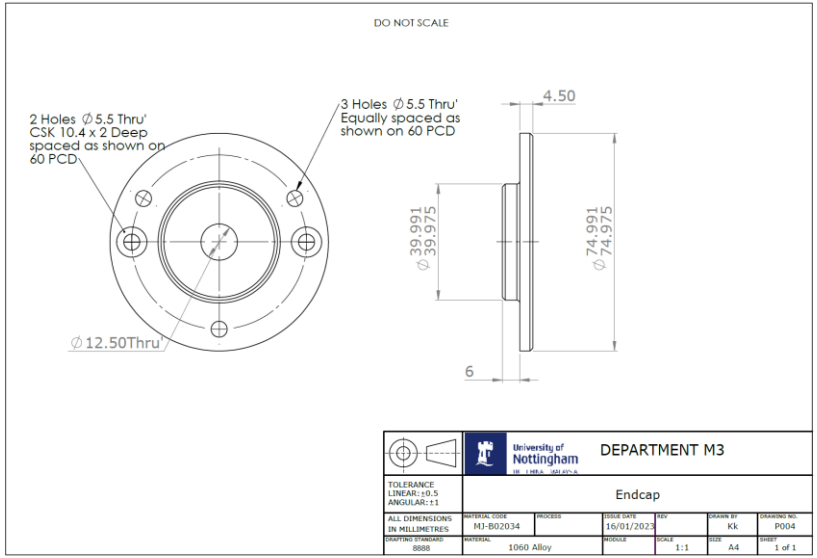

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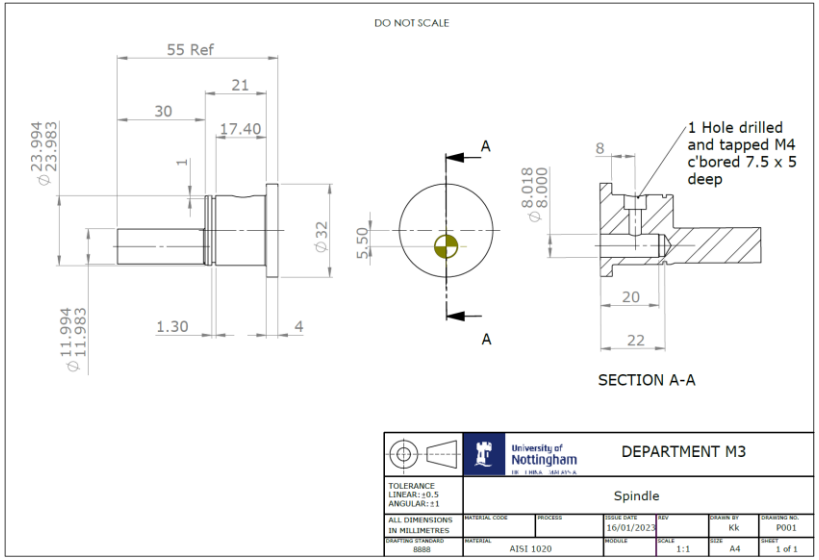
Detail Drawings



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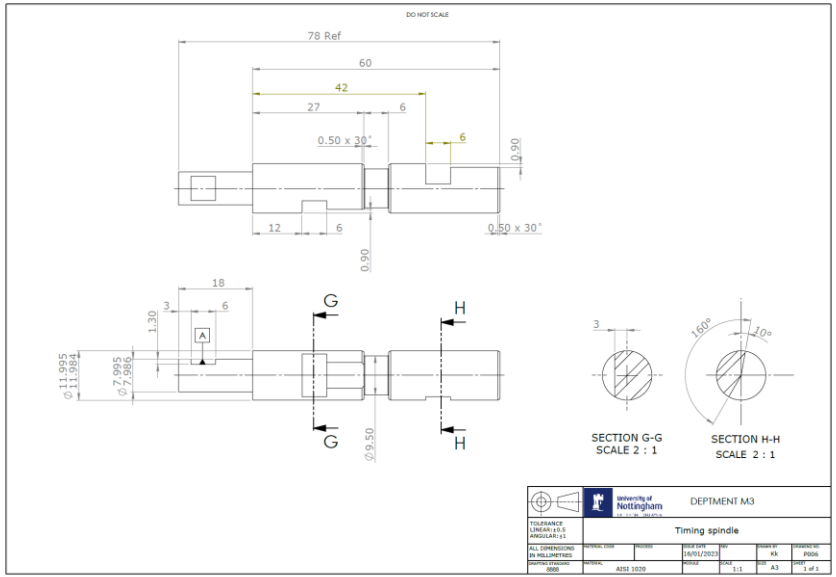

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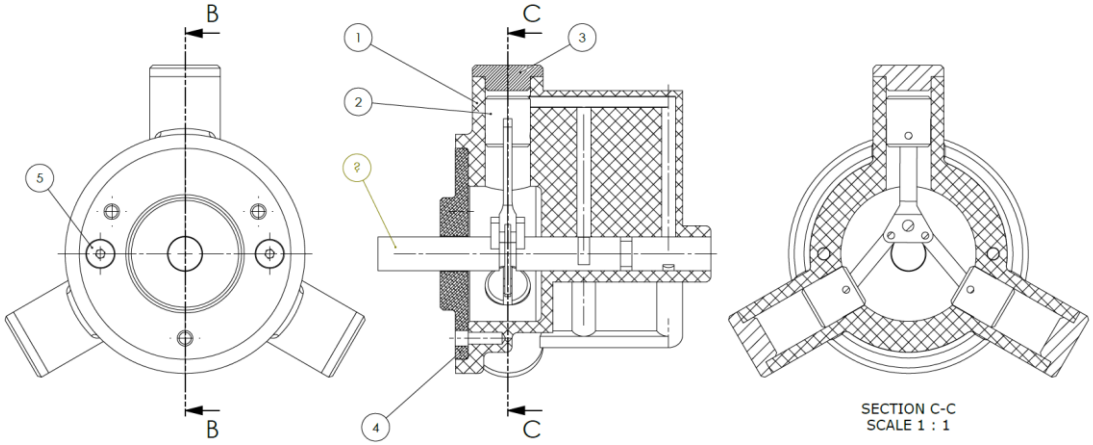
Air Motor - Cranked

ITEM	DRAWING NO.	DESCRIPTION (DO NOT SCALE)	MATERIAL	MATERIAL CODE	VENDOR	PART No	QTY.
1	P002	Cylinder Body	PLA				1
2	P005	Piston	1060 Alloy	MJ-B02012	L2 Stores		3
3	P007	Cylinder Cap	PBT				3
4	P004	Endcap	1060 Alloy	MJ-B02034	L2 Stores		1
5		Csk Skt Head Screw M5 x 16	Steel		L2 Stores	MH-D04017	2
6		Air Connection	B/O		Legris	3601_06_10	1
7	A002	Rotor Assembly					1



SECTION B-B
SCALE 1 : 1

SECTION C-C
SCALE 1 : 1

TOLERANCE LINEAR: ± 0.5 ANGULAR: ± 1°	University of Nottingham	DEPARTMENT M3
	AIR MOTOR ASSEMBLY AM BODY	
ALL DIMENSIONS ARE IN MILLIMETRES	ISSUE DATE 01/02/2021	REVISION
DRAWN BY Kk	DRAWING NO. A001	
DRAFTING STANDARD BS 8888	MODULE MMME 2044	SCALE 1:1
SIZE A3	SHEET 1 of 1	

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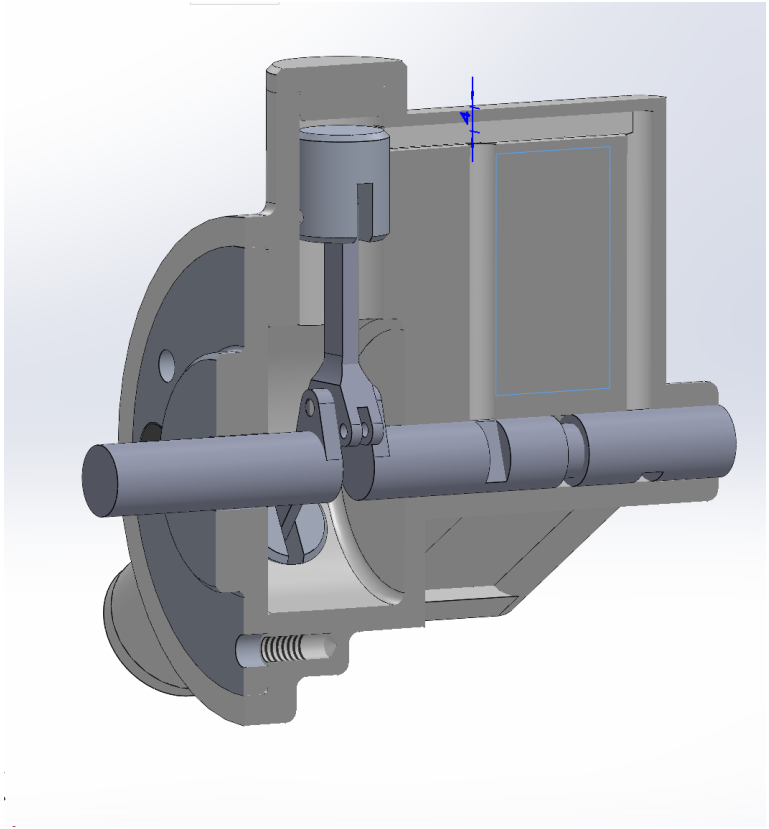
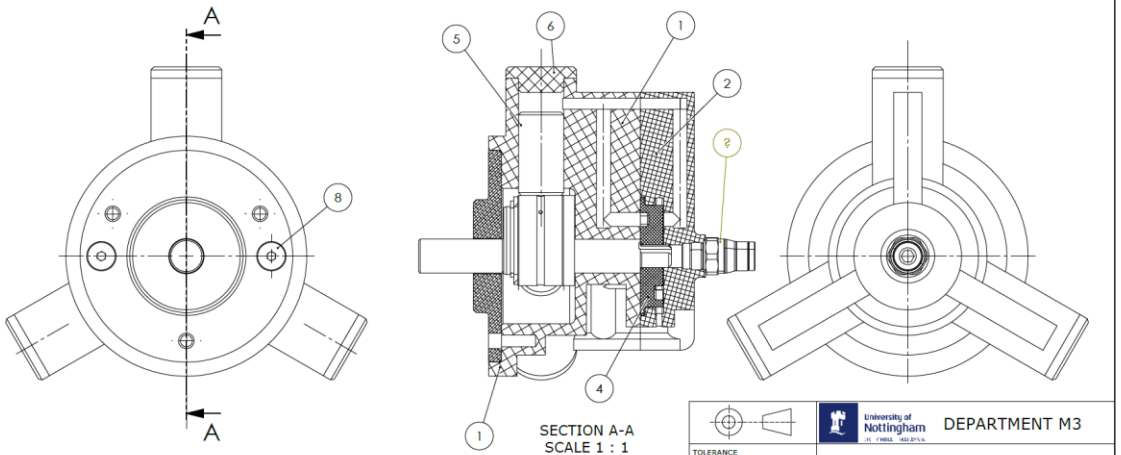
Air Motor - Cranked



Air Motor - Rotary Valve

DO NOT SCALE

ITEM	DRAWING NO.	DESCRIPTION	MATERIAL	MATERIAL CODE	VENDOR	PART No	QTY.
1	P002	Cylinder Body	PBT General Purpose				1
2	P009	Exhaust Manifold	PBT General Purpose				1
3		Air Connection	B/O		Legris		1
4	A002	Distributor Assembly					1
5	P005	Piston	1060 Alloy	MJ-B02012	L2 Stores		3
6	P007	Cylinder Cap	PBT General Purpose				3
7	P004	Endcap	1060 Alloy	MJ-B02034	L2 Stores		1
8		Csk Skt Head Screw M5 x 10	Steel		L2 Stores	MH-D04014	2



SECTION A-A
SCALE 1 : 1

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AIR MOTOR - ROTARY VALVE

TOLERANCE
LINEAR: ± 0.5
ANGULAR: ± 1°

ALL DIMENSIONS ARE IN MILLIMETRES

DRAFTING STANDARD: BS 8888

ISSUE DATE: 01/02/2021
REVISION:
DRAWN BY: Kk
DRAWING NO.: A001
MODULE:
SCALE: 1:2
SIZE: A3
SHEET: 1 of 1

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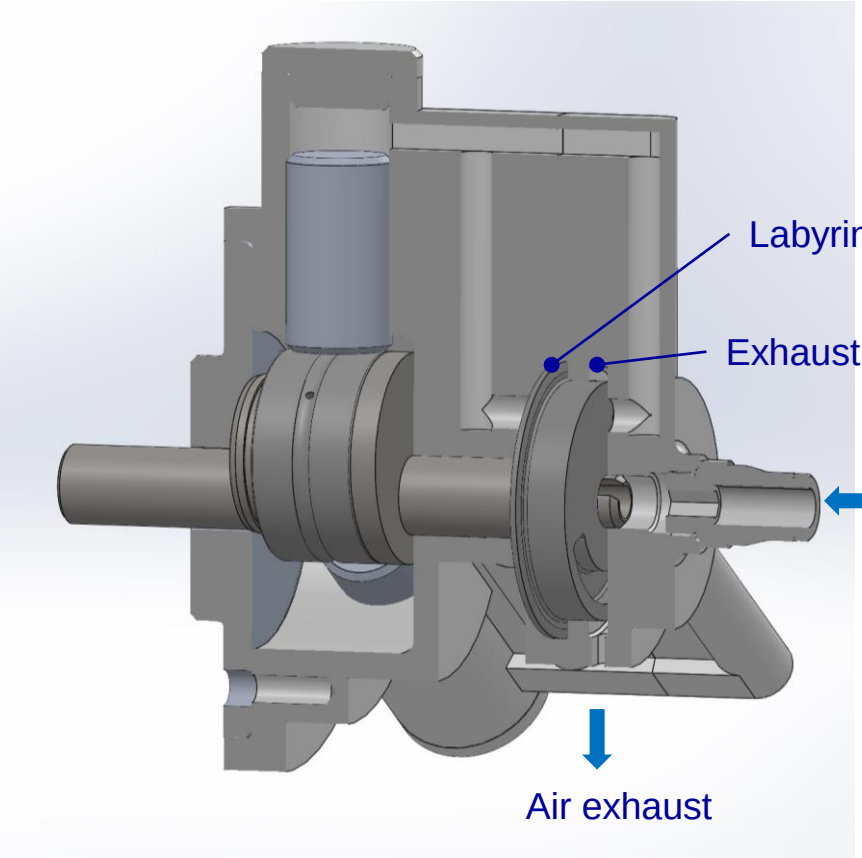
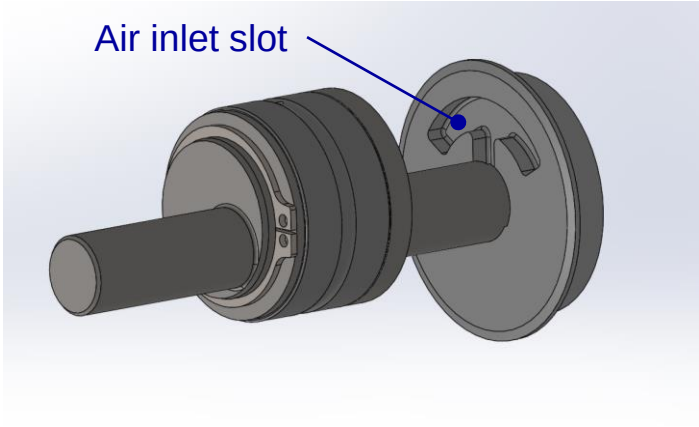
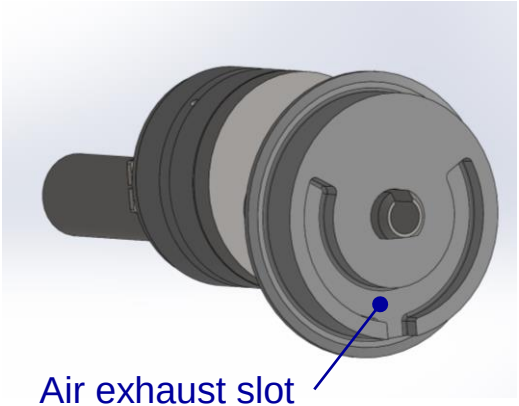
Air Motor - Rotary Valve

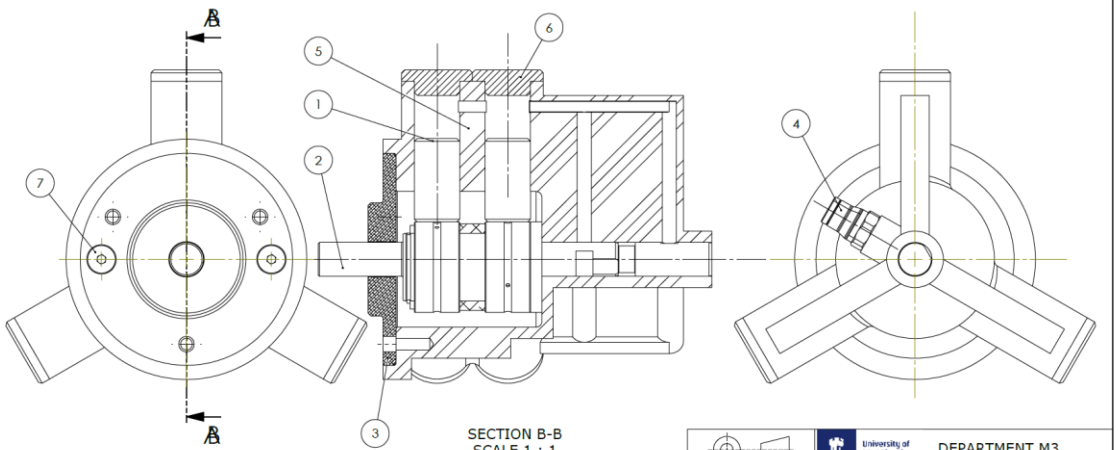






Air Motor – Twin Cylinder

ITEM	DRAWING NO.	DESCRIPTION (DO NOT SCALE)	MATERIAL	MATERIAL CODE	VENDOR	PART No	QTY.
1	P005	Piston	1060 Alloy	MJ-B02012	L2 Stores		6
2	A002	Rotor Assembly					1
3	P004	Endcap	1060 Alloy	MJ-B02034	L2 Stores		1
4		Air Connection	B/O		Legris	3601_06_10	1
5	A001	Cylinder Body	Nylon 12				1
6	P007	Cylinder Cap	Nylon 12				6
7		Csk Skt Head Screw M5 x 10	Steel		L2 Stores	MH-D04014	2



SECTION B-B
SCALE 1 : 1

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TOLERANCE
LINEAR: ± 0.5
ANGULAR: ± 1°

AIR MOTOR ASSEMBLY AM BODY

ALL DIMENSIONS ARE IN MILLIMETRES	ISSUE DATE	REVISION	DRAWN BY	DRAWING NO.
	14/01/2023		Kk	A001
DRAFTING STANDARD: BS 8888	MODULE: MMME 2044	SCALE: 1:1	SIZE: A3	SHEET: 1 of 1

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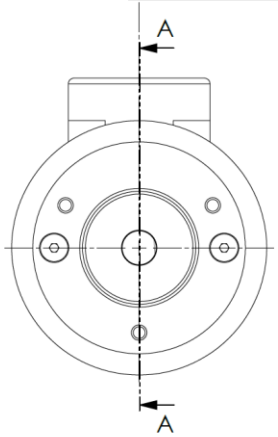
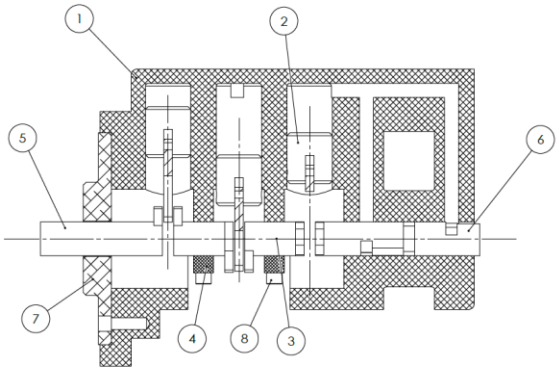
Air Motor - Inline

DO NOT SCALE

ITEM	DRAWING NO.	DESCRIPTION	MATERIAL	MATERIAL CODE	VENDOR	PART No	QTY.
1	P001	Air Motor Body	PBT General Purpose				1
2	A002	Piston and Con Rod Assembly					3
3	P004	Intershaft	AISI 1020				2
4	P005	Bearing Cap	PBT General Purpose				2
5	P002	Output Shaft	AISI 1020				1
6	P004	Timng Shaft	AISI 1020				1
7	P004	Endcap	1060 Alloy	MJ-B02034	L2 Stores		1
8		Skt HD Screw M3 x 20	Steel		L2 Stores	MJ-03011	4
9		Csk Skt Head Screw M5 x 10	Steel		L2 Stores	MH-D04014	2





SECTION A-A
SCALE 1 : 1

University of Nottingham

TOLERANCE LINEAR: ± 0.5 ANGULAR: ± 1°	Air Motor Assembly			
ALL DIMENSIONS ARE IN MILLIMETRES	ISSUE DATE 13/11/2020	REVISION	DRAWN BY Kk	DRAWING NO. A001
DRAFTING STANDARD BS 8888	MODULE	SCALE 1:2	SIZE A3	SHEET 1 of 2

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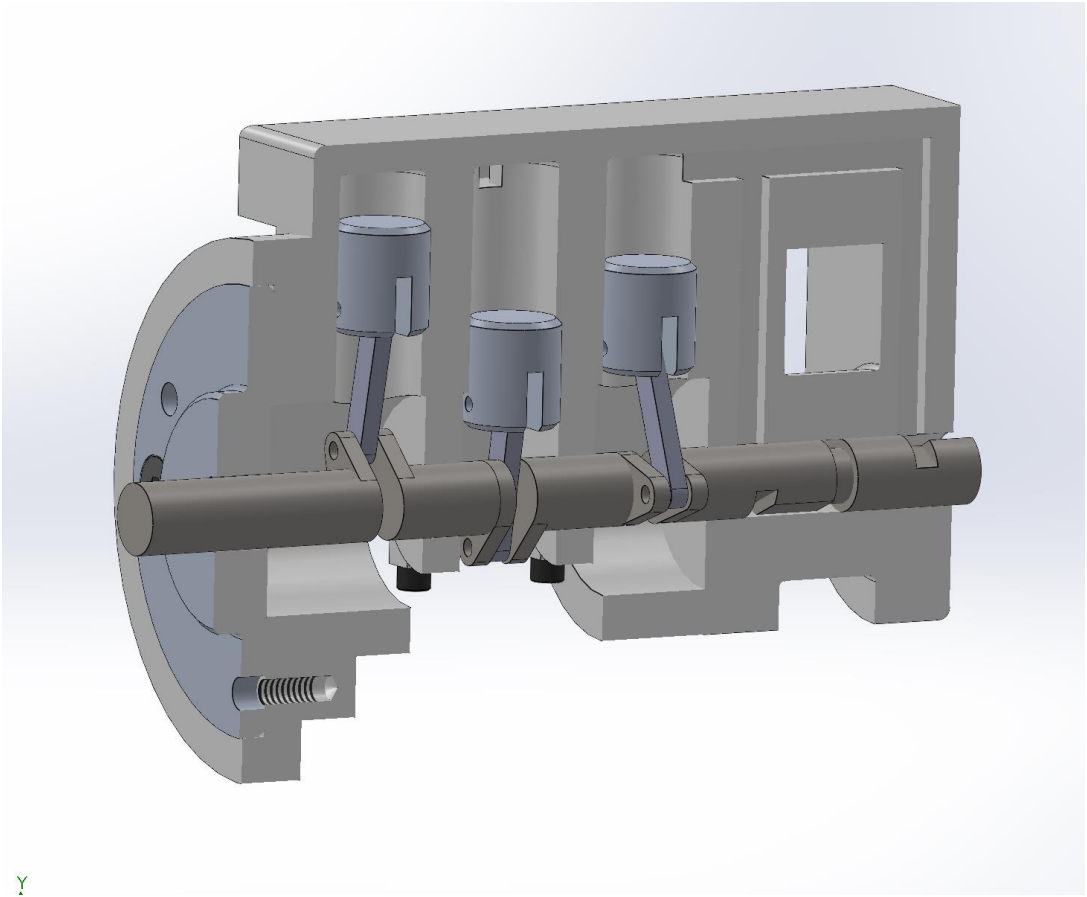
Air Motor - Inline



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