MMME2044 Group Design & Make

Air Motor

Clinic session for CDR

Dr Hengan Ou

Coates B80a

h.ou@nottingham.ac.uk

Outline of session

The purpose of the CDR clinic session is

- to discuss and clarify questions on CDR submission
- to recap a few points of CDR pro-forma
- to show examples on design and calculations

Critical Design Review (CDR)

The CDR submission is to present

- a satisfactory design solution to meet stated requirements,
- a complete record/documentation of the project to date.

The **CDR report** should be presented using the provided **CDR pro-forma**

- ➢ A CDR check List
- ➢ Executive summary
- ➢ Engineering and design rationale
- ➢ Calculations
- ➢ GA (General Arrangement) drawings
- ➢ Detail drawings and process sheets
- ➢ Manufacturing plan, Cutting List and Part List for 3D Printing
- ➢ Team working and individual contribution

Group CDR submission on Moodle

- The CDR submission should be put in **a zipped folder** and submitted on **Moodle by 3pm, Friday, 9th December**.
- The CDR report is a **Summative submission**. It is worth **20% of the MMME 2044 module**.
- The **CDR pro-forma and template folders/files** are available in the **Group D&M project folder** in the **Design Tutorial and Support** on Moodle
- Make sure your **CDR report** (a single file in PDF format) is compiled in **a clear and concise manner** to recommended pages.
- Place your CDR report, spreadsheet/hand-written files and Solidworks models and drawings in separate folders as from the template

Preparation of CDR report

Executive summary (1 page per group, 400 words max)

- Give a CONCISE summary of your group's design solution of the air motor,
  - The group's assessment to the UAP Board's questions
  - A very brief discussion on specific features of design for proper function and attention for easy manufacturing in the next stage of the project.

Table of content (optional)

Preparation of CDR report

Engineering and Design Rationale (3 pages max per group)

- Present an **updated statement of requirements** in tabular form.
- Present your **rationale and assessment** to the following questions:
  - How does the group's design solution work?
  - Are all the functions of design satisfied?

    Present **an updated morphology chart** filling the boxes showing how the **Final Design achieves all the functions** and **justify that the architecture is highly probable** to that of the RAP motor.
  - What are the strengths and weaknesses of the design?
  - Is it likely to be a low cost product?
  - Can your designed air motor be tested using the UAP's existing test rig?

Preparation of CDR report

Engineering and Design Rationale (cont'd)

- You may use Solidworks assembly **images and/or cutaway views** to identify key parts and design features and to describe how the air motor operates for the intended functions.

B-4 Interfaces:

Interfaces were created to accommodate the ancillary devices onto the engine block. This allows for easy assembly and attachment. The following figures show two isometric views of the engine block, which shows the interfaces.

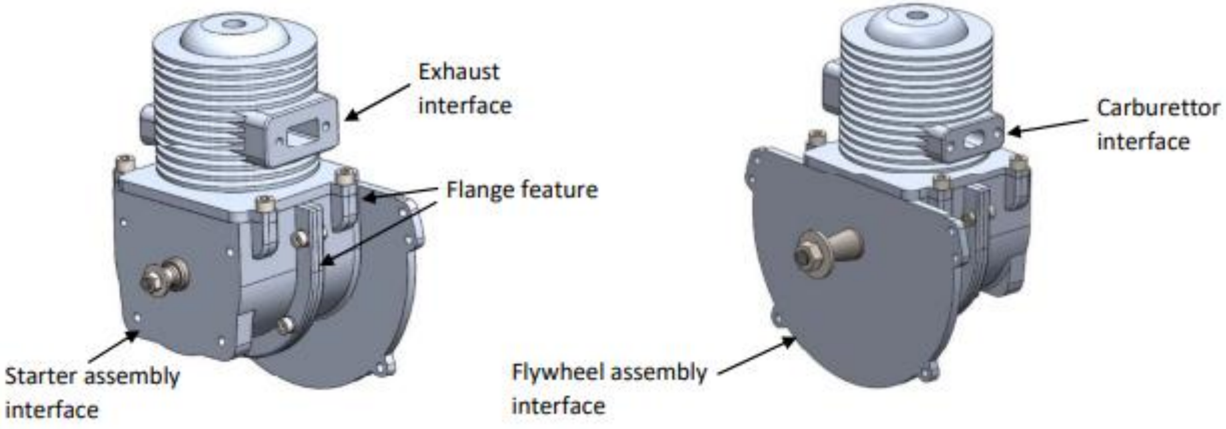


Figure 3: Two isometric views of the engine block showing the interfaces

B-3 Mounting of the cylinder/crankcase

To ensure proper alignment of the piston head to the crankcase, a circular sleeve feature has been added which provides proper mounting which fits into the crankcase.a flange feature has been embodied in the design and 4 M5 bolths will be used to connect the cylinder heaad to the crankcase.The following figure is a cross section of the engine block showing all of the designed components along with the mounting of the bearings.

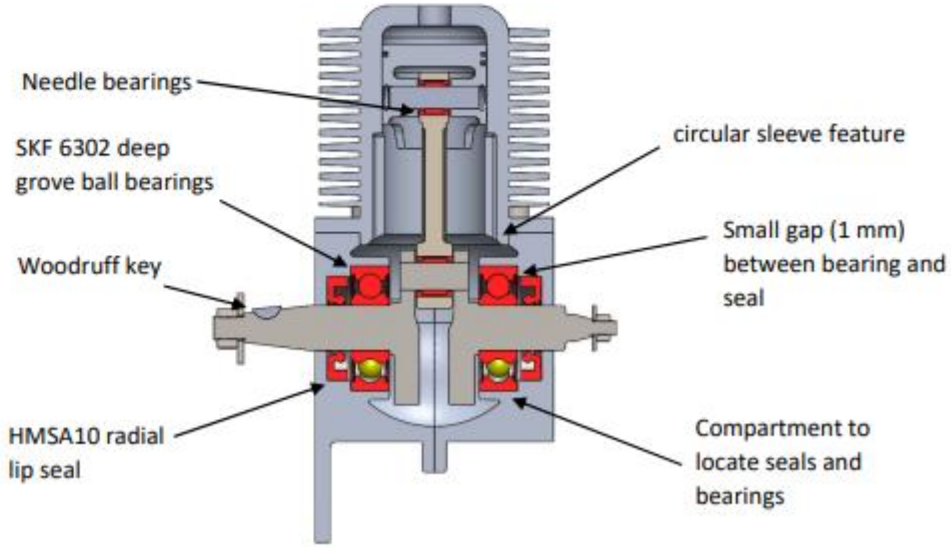


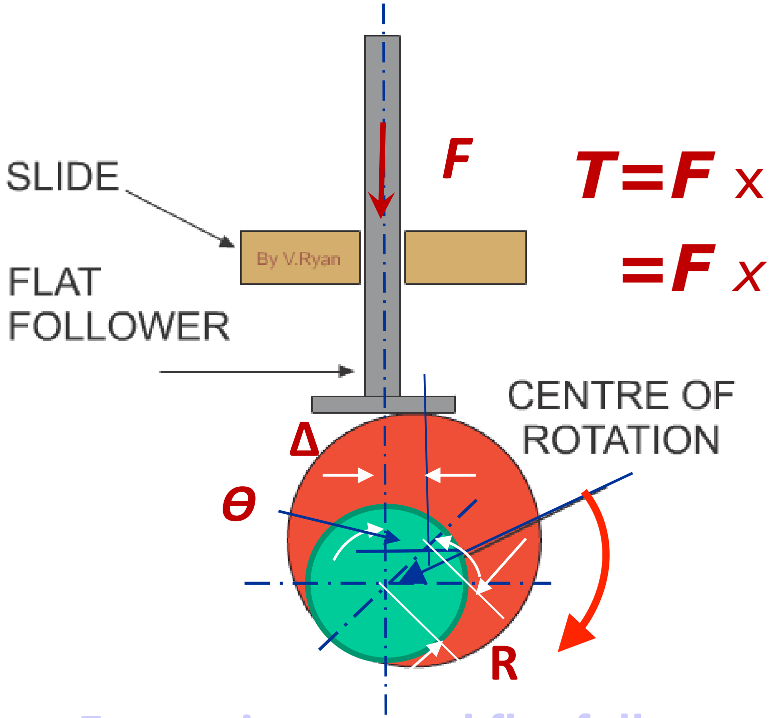
Figure 2: cross section of the engine block, showig the layout of the engine components.

An example of individual design: 2-stroke engine (available on Moodle)

Preparation of CDR report

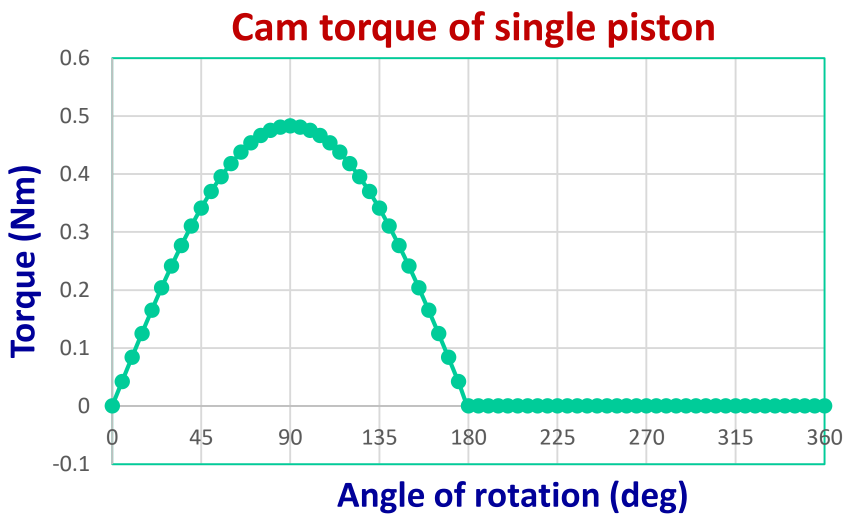
Calculations (2~3 pages)

- **Present a summary of key equations and summary of results** of the force, torque and power calculations. Other calculations may include the calculations of stressed or critically loaded parts, e.g. output shaft.
- **Detailed spreadsheet or hand calculations should be included in separate files.**



$$T = F \times \Delta$$
$$= F \times R \times \sin\theta$$

Eccentric cam and flat follower



Example spreadsheet available on Moodle

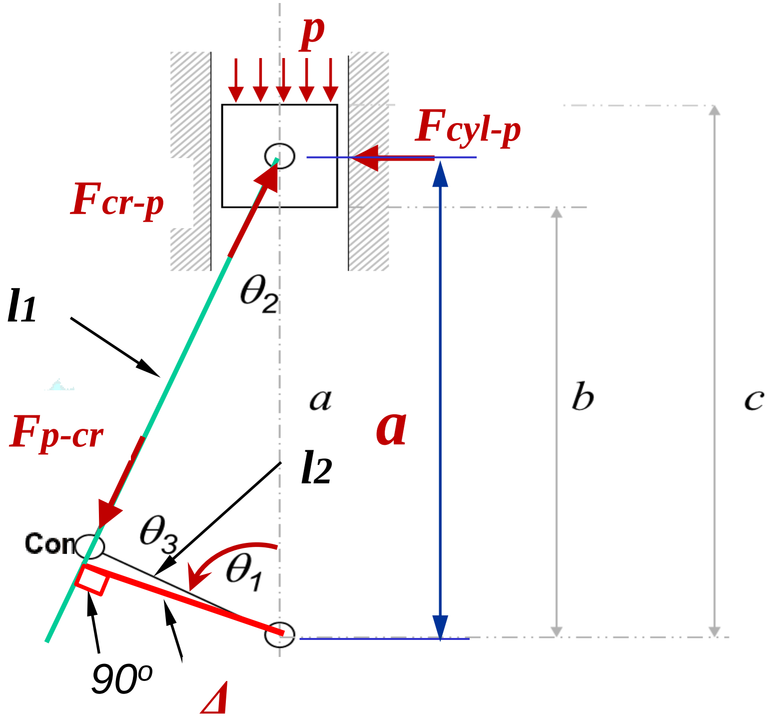
Preparation of CDR report

Calculations (cont'd)

For a crank design configuration: $\boldsymbol{T = F_{p-cr} \times \Delta}$

From free-body diagram of piston:

$$\boldsymbol{F_{p-cr}} = \frac{\frac{\pi}{4} D^2 \times \boldsymbol{p}}{\cos\theta_2}$$



Based on law of sines:

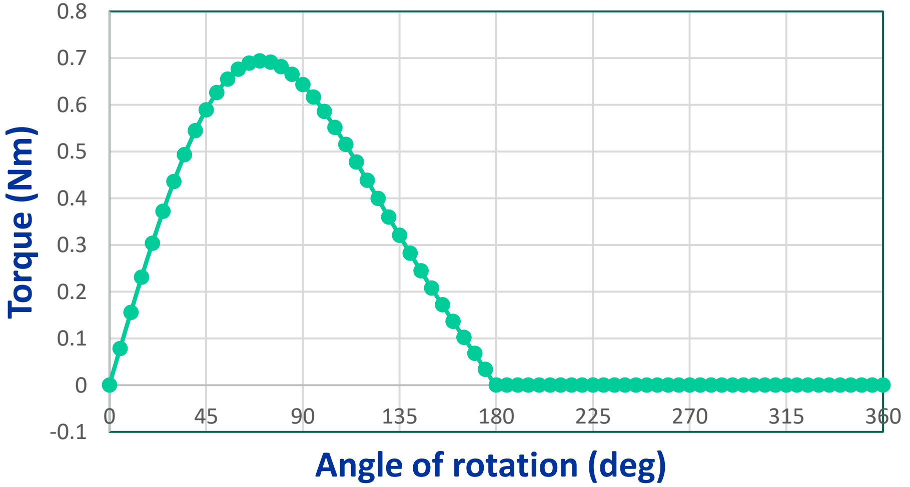
$$\theta_2 = \sin^{-1}\left(\frac{l_2}{l_1}\sin\theta_1\right)$$

Torque arm R should be

$$\boldsymbol{\Delta} = a\sin\theta_2$$

and

$$\boldsymbol{a = l_2 \cos\theta_1 + l_1\sqrt{1-\left(\frac{l_2}{l_1}\sin\theta_1\right)^2}}$$



where, ***T*** is torque (Nm)

Fp-cr is force by piston to conrod (N)

Δ is torque arm (m)

l1 and ***l2*** are conrod length and crank radius (m)

p is gas pressure (Pa) & ***D*** is piston diameter (m)

Preparation of CDR report

Calculations (cont'd)

Stress calculation of critical loading parts (e.g. shaft or shear pins).

You may use ASME Shaft Design Equation (refer Shaft Design Lecture slides & handouts) or the equations for shear stresses due to torsion or direct shear in your calculation.

$$d = \left[\frac{32 n_s}{\pi} \sqrt{\left(\frac{M}{\sigma_e}\right)^2 + \frac{3}{4}\left(\frac{T}{\sigma_y}\right)^2} \right]^{1/3}$$

Min diameter (m)

Reserve or safety factor (often use 2)

Max torque on shaft (**Nm**)

Yield strength of shaft material (Pa)

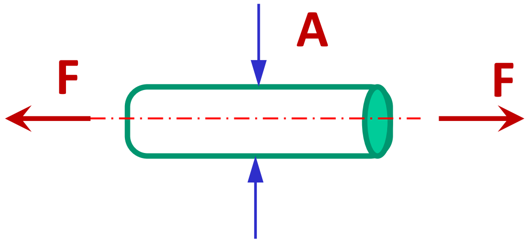
Max bending moment on shaft (**Nm**)

Endurance limit stress (Pa)

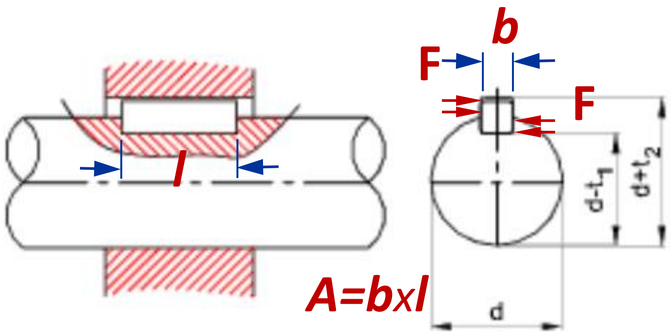
Example spreadsheet of ASME shaft calculation of 1st year Spring Powered Cart available on Moodle

Common types of loading and stresses

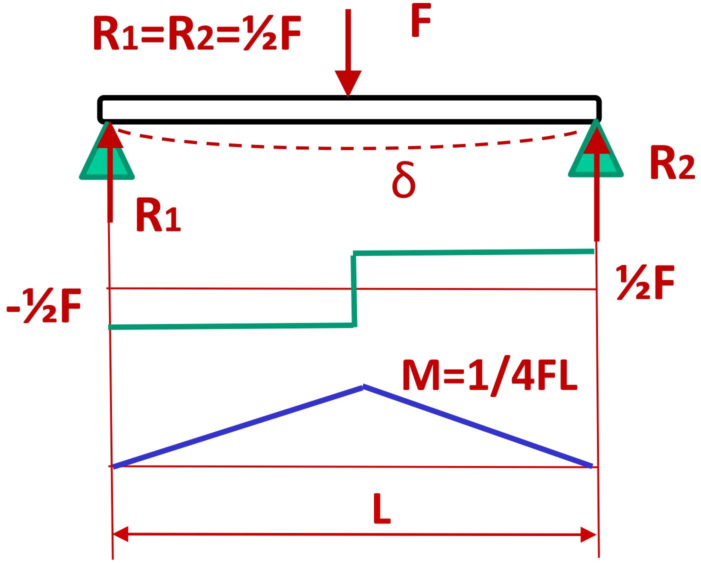
- **Types of loading & stress**
  - Tensile load $\sigma = \frac{F}{A}$
  - Direct shear $\tau = \frac{F}{A}$
  - **Bending** $\sigma = \frac{My}{I}$
  - **Torsion** $\tau = \frac{TR}{J}$



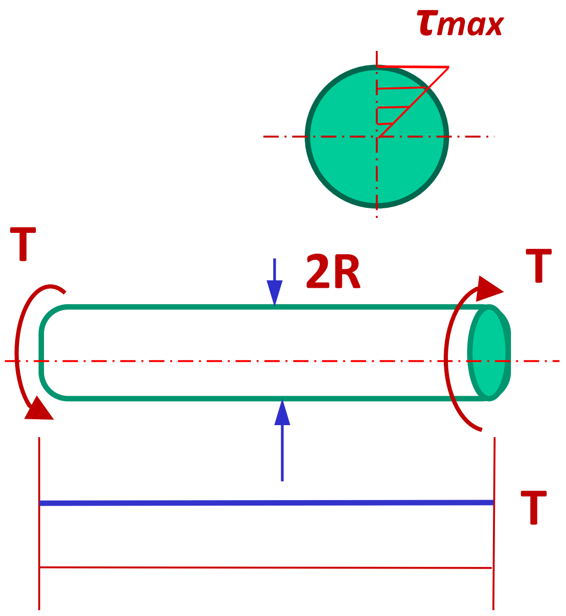
Tensile stress



Direct shear stress



Bending moment & shear force



Shear due to torsion

Preparation of CDR report

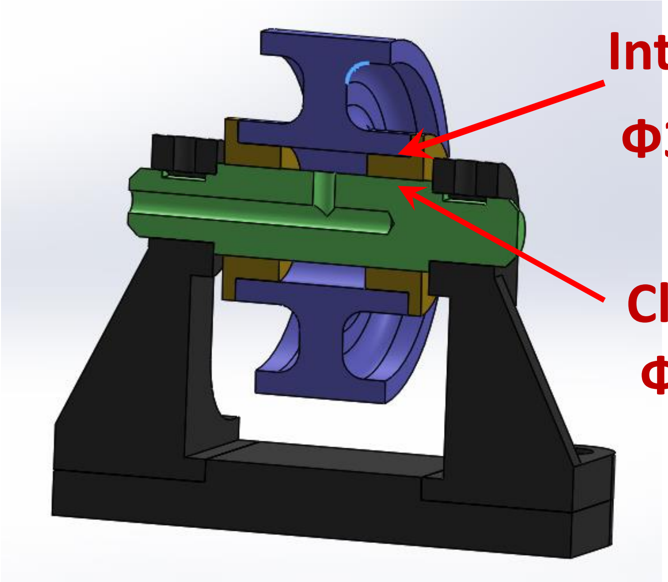
Assembly drawings (2~3 A3 drawing sheets)

- **General Arrangement (GA) drawings** are to show the assembled air motor for **intended functions,** to identify all parts using **BOM balloons itemised in the Part List table**, and to specify **necessary fits and assembly instructions**.
- The GA drawings should show clearly the detailed design of the air motor **using sections, views** and partial views if necessary. The GA drawings should also include all **title block information** to BS 8888 standard.
  - Appropriate choice of views, including placement of cross sections and use of detailed views to show smaller details at larger scale.
  - Appropriate use of ISO standard fits on any critical interfaces between components.
  - Appropriate exclusions of features from cross-sections, i.e. fasteners and features with no internal details such as solid shafts.
  - Appropriate selection of cross-section hatch spacing and angle to show separation of adjacent parts.
  - Appropriate placement of BOM table and BOM balloons.
  - Appropriate notation of critical fits between components.

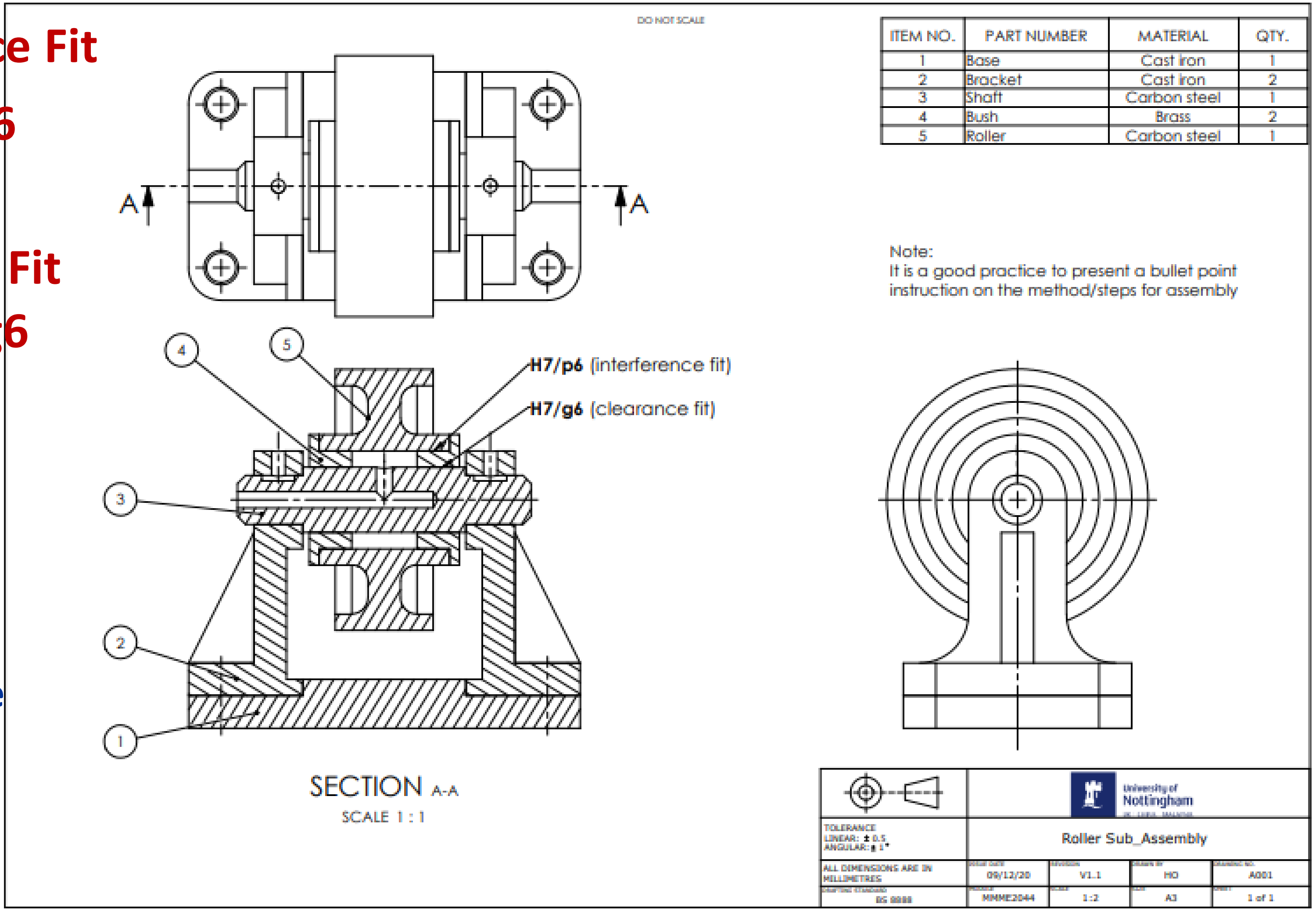
Preparation of CDR report

Assembly drawings (cont'd)

An example GA of a roller-subassembly (an exercise of CAE3)



Roller subassembly from 1st year EDP (see CAE 3 brief slides and SW models on Moodle)



SOLIDWORKS Educational Product. For Instructional Use Only.

- More GA drawings including GAs of a 2-stroke engine are available on Moodle
- In CDR submission, PRINT GA and detail drawings in PDF and combine the drawing sheets with the rest of CDR report

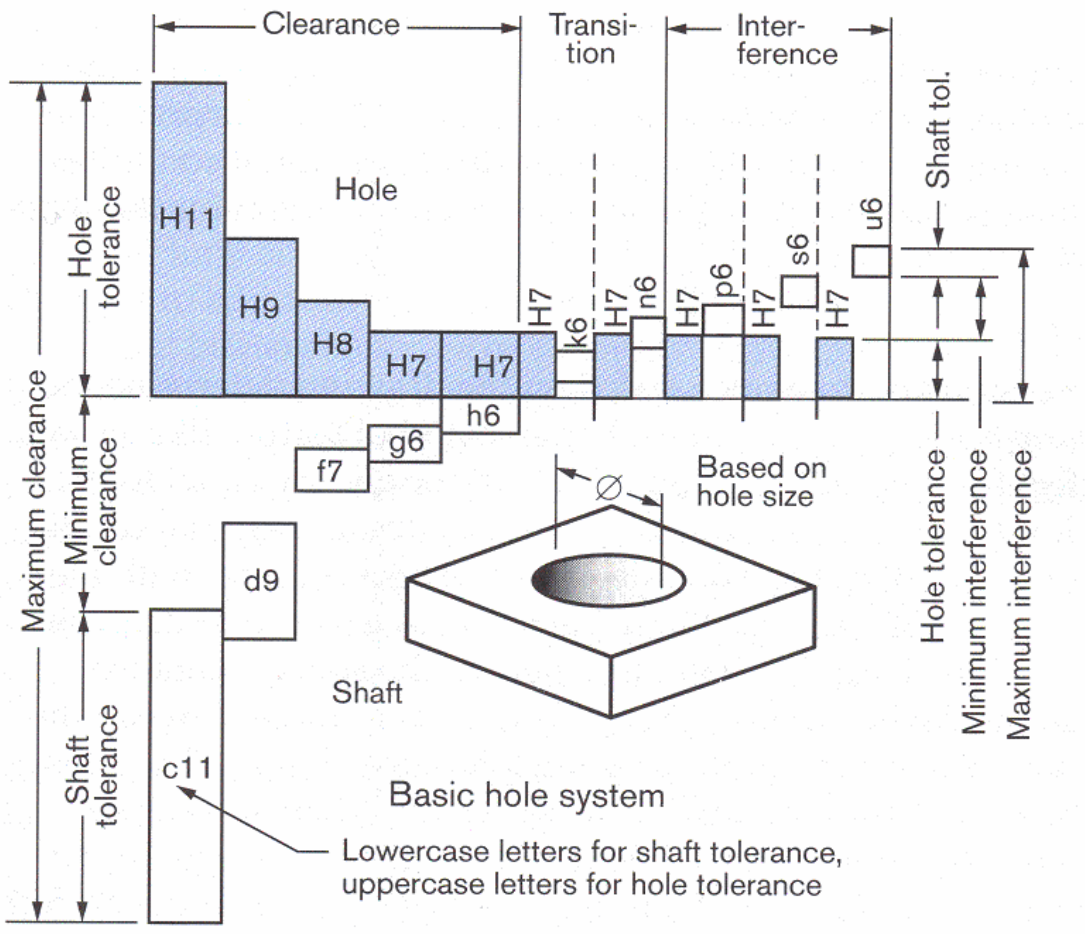
Preparation of CDR report

Assembly drawings (cont'd)

Fits specification using BS 4500A (Hole Basis) (available on Moodle)

Fits are defined to ensure proper function of a machine system:

- **Clearance fits:** shaft smaller than hole to leave a clearance
- **Transition fits:** shaft slightly bigger or smaller than hole for an interference or clearance
- **Interference fits:** shaft bigger than hole to prevent relative motion



Specification of Fits in GA and Tolerances in Detail Drawings

Roller-Sub Assembly as an example (Use BS4500 A)

INTERFERENCE FIT

for Roller & Bushes (Φ30)

H7/p6 is the solution

Roller as Hole:

$$\varnothing 30^{+0.021}_{0}$$

Bush as Shaft:

$$\varnothing 30^{+0.035}_{+0.022}$$

CLEARANCE FIT

for Bushes & Shaft (Φ20)

H7/g6 is a choice

Bush as Hole:

$$\varnothing 20^{+0.021}_{0}$$

Shaft is Shaft:

$$\varnothing 20^{-0.007}_{-0.020}$$

Extracted from BS 4500 : 1969

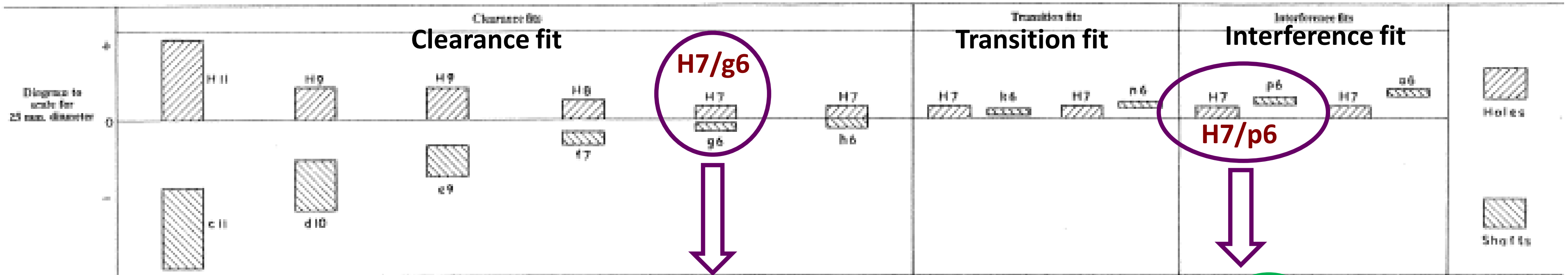
BRITISH STANDARD

SELECTED ISO FITS—HOLE BASIS

Data Sheet 4500A

Issue 1. February 1970

Confirmed August 1985



Nominal sizes Over mm	To mm	H11 0·001 mm	c11 0·001 mm	H9 0·001 mm	d10 0·001 mm	H9 0·001 mm	e9 0·001 mm	H8 0·001 mm	f7 0·001 mm	H7 0·001 mm	g6 0·001 mm	H7 0·001 mm	h6 0·001 mm	H7 0·001 mm	k6 0·001 mm	H7 0·001 mm	n6 0·001 mm	H7 0·001 mm	p6 0·001 mm	H7 0·001 mm	s6 0·001 mm	Nominal sizes Over mm	To mm
—	3	+60 / 0	−60 / −120	+25 / 0	−20 / −60	+25 / 0	−14 / −39	+14 / 0	−6 / −16	+10 / 0	−2 / −8	+10 / 0	−6 / 0	+10 / 0	+6 / 0	+10 / 0	+10 / +4	+10 / 0	+12 / +6	+10 / 0	+20 / +14	—	3
3	6	+75 / 0	−70 / −145	+30 / 0	−30 / −78	+30 / 0	−20 / −50	+18 / 0	−10 / −22	+12 / 0	−4 / −12	+12 / 0	−8 / 0	+12 / 0	+9 / +1	+12 / 0	+16 / +8	+12 / 0	+20 / +12	+12 / 0	+27 / +19	3	6
6	10	+90 / 0	−80 / −170	+36 / 0	−40 / −98	+36 / 0	−25 / −61	+22 / 0	−13 / −28	+15 / 0	−5 / −14	+15 / 0	−9 / 0	+15 / 0	+10 / +1	+15 / 0	+19 / +10	+15 / 0	+24 / +15	+15 / 0	+32 / +23	6	10
10	18	+110 / 0	−95 / −205	+43 / 0	−50 / −120	+43 / 0	−32 / −75	+27 / 0	−16 / −34	+18 / 0	−6 / −17	+18 / 0	−11 / 0	+18 / 0	+12 / +1	+18 / 0	+23 / +12	+18 / 0	+29 / +18	+18 / 0	+39 / +28	10	18
18	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+33 / 0	−20 / −41	+21 / 0	−7 / −20	+21 / 0	−13 / 0	+21 / 0	+15 / +2	+21 / 0	+28 / +15	+21 / 0	+35 / +22	[illegible]	[illegible]	18	30
30	40	+160 / 0	−120 / −280	+62 / 0	−80 / −180	+62 / 0	−50 / −112	+39 / 0	−25 / −50	+25 / 0	−9 / −25	+25 / 0	−16 / 0	+25 / 0	+18 / +2	+25 / 0	+33 / +17	+25 / 0	+42 / +26	+25 / 0	+59 / +43	30	40
40	50	+160 / 0	−130 / −290																			40	50
50	65	+190 / 0	−140 / −330	+74 / 0	−100 / −220	+74 / 0	−60 / −134	+46 / 0	−30 / −60	+30 / 0	−10 / −29	+30 / 0	−19 / 0	+30 / 0	+21 / +2	+30 / 0	+39 / +20	+30 / 0	+51 / +32	+30 / 0	+72 / +53	50	65
65	80	+190 / 0	−150 / −340																	+30 / 0	+78 / +59	65	80
80	100	+220 / 0	−170 / −390	+87 / 0	−120 / −260	+87 / 0	−72 / −159	+54 / 0	−36 / −71	+35 / 0	−12 / −34	+35 / 0	−22 / 0	+35 / 0	+25 / +3	+35 / 0	+45 / +23	+35 / 0	+59 / +37	+35 / 0	+93 / +71	80	100
100	120	+220 / 0	−180 / −400																	+35 / 0	+101 / +79	100	120
120	140	+250 / 0	−200 / −450	+100 / 0	−145 / −305	+100 / 0	−85 / −185	+63 / 0	−43 / −83	+40 / 0	−14 / −39	+40 / 0	−25 / 0	+40 / 0	+28 / +3	+40 / 0	+52 / +27	+40 / 0	+68 / +43	+40 / 0	+117 / +92	120	140
140	160	+250 / 0	−210 / −460																	+40 / 0	+125 / +100	140	160
160	180	+250 / 0	−230 / −480																	+40 / 0	+133 / +108	160	180
180	200	+290 / 0	−240 / −530																	+46 / 0	+151 / +122	180	200

Note: BS 4500A & BS 4500B charts are available on Moodle

Preparation of CDR report

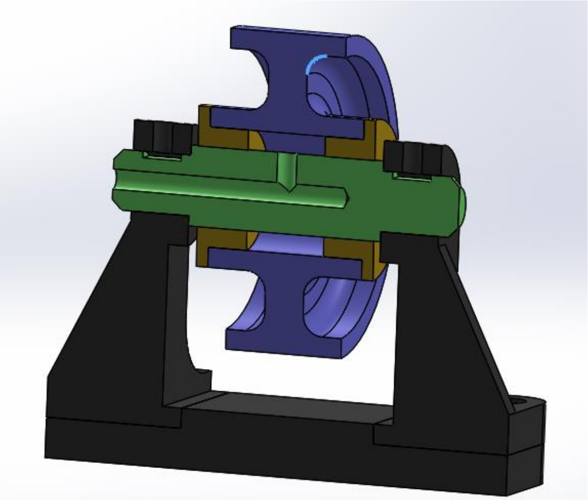
Detail drawings and process sheets (no page limit but need to be concisely presented)

- **A detail drawing** should include **all the necessary information required for the definition of the part**, e.g. material, properties, dimensions and tolerances.
- **Dimensions and tolerances** are clearly defined for **intended function, easy manufacturing and inspection with datum feature established**.
- Only for a **machined part**, a **process sheet** is required to describe every step of the manufacturing process.
    - A complete set of required dimensions, drawn from appropriate datums.
    - Tolerances on all dimensions that have a specified fit in the GA drawing.
    - Appropriate part naming conventions matching the GA bill of materials.

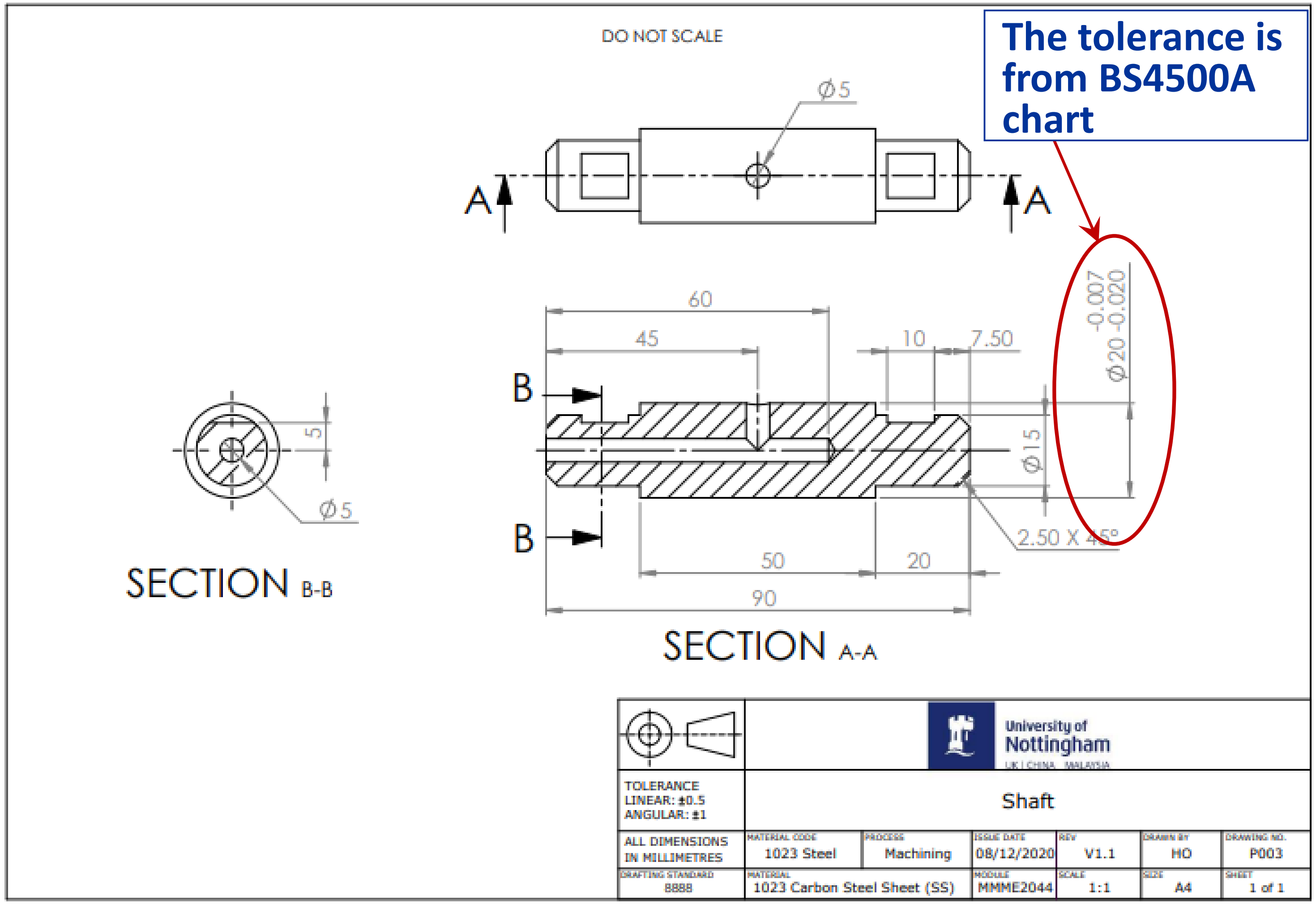
Preparation of CDR report

Detail drawings and process sheets (cont'd)

Roller-subassembly: Detail drawing of the Shaft



Roller subassembly from 1st year EDP (see CAE 3 brief slides and SW models on Moodle



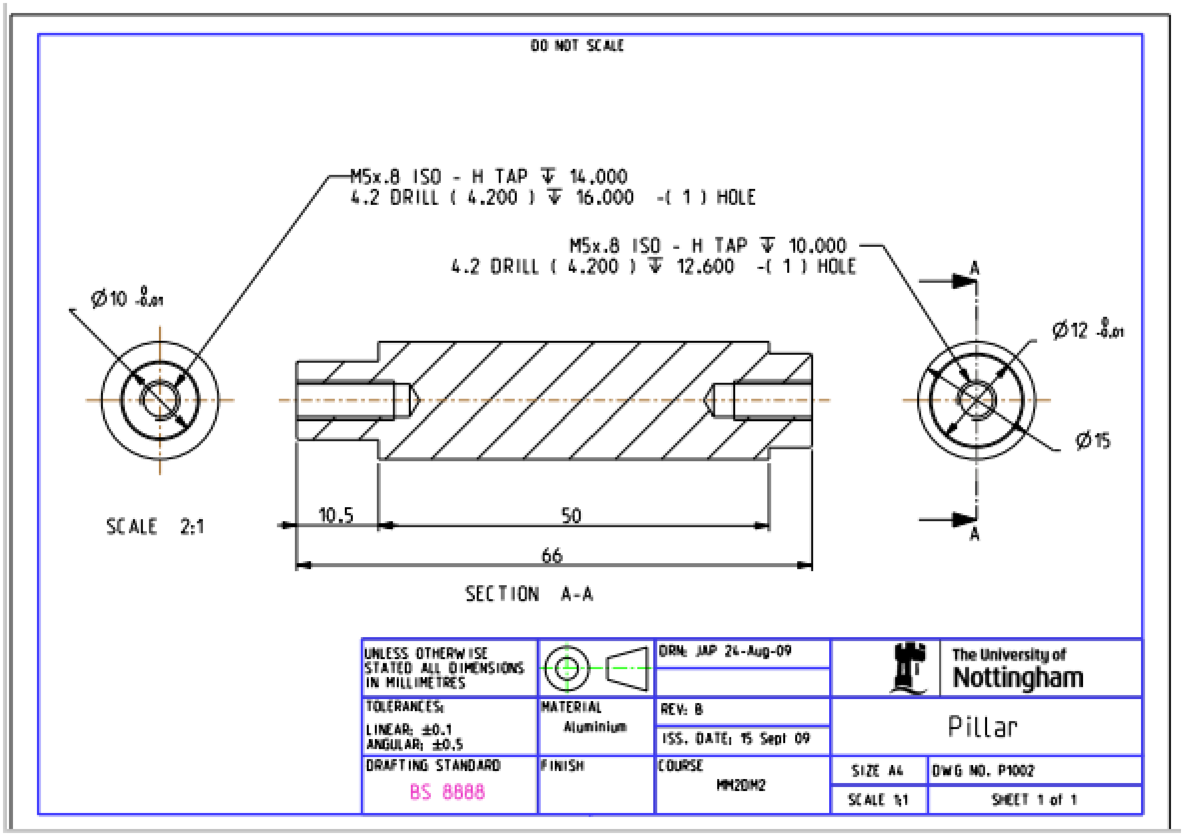
The tolerance is from BS4500A chart

No need of PROCESS SHEET for a 3D Printed part!

Preparation of CDR report

Detail drawings and process sheets (cont'd)

Sample drawing and process sheets available on Moodle



MM2DM2-Autumn 2009

The University of Nottingham

Process Sheet

Operation No	Operation Description	Machine	Special Tools	Notes
1.	**Chuck** stock in 3-jaw enough projecting for one pillar and face off	Lathe		Start with sufficient for a batch of 4 to avoid wasted ends. 8 would have stock protruding dangerously from headstock.
2.	**Centre drill**	Lathe		
3.	**Turn** OD to finished size and **turn** smaller diameter end.	Lathe		Support work with tailstock.
4.	**Drill** tapping size at small end and **tap**	Lathe		Steady tap in tailstock centre. Work turned by hand not under power for tapping
5.	**Turn** large end to size 3 mm longer than finished part.	Lathe	Parting/grooving tool	Cut to give accurate finished length. Use of same setting for 3 and 5 ensures concentricity
6.	**Part off** to finished length	Lathe	Parting tool	Note dimensioning

Drawing No	Item No	Description	Material	Sheet 1 of 2
P1002 Rev A		Pillar	Aluminium	

MM2DM2-Autumn 2009

Process Sheet

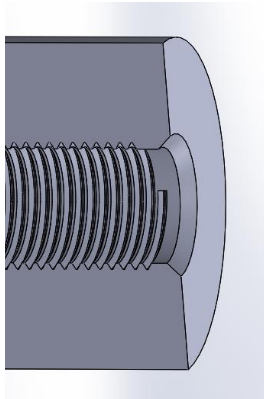
				scheme avoids machinist doing calcs.
7.	**Re-chuck** part reversed. **Centre drill**, tapping drill and **tap** large end.	Lathe		Steady tap with tailstock

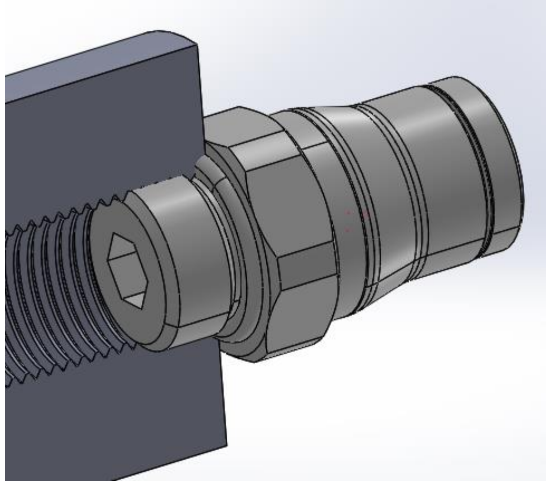
Use template Process sheet available on Moodle

Preparation of CDR report

Cutting list, Part list for 3D printing and Manufacturing plan (3~5 pages per group)

- Use the **blank Cutting List for machining** (available on Moodle) to describe all materials needed for machining.
- Use the **blank Part List for 3D printing** (available on Moodle) to give a list of parts of all 3D printed parts.
- Present an **agreed manufacturing plan**, which includes individual member's responsibilities and roles for identified tasks. A **champion for machining** and a **champion for 3D printing.**
- **Create an imperial thread Solidworks** for proper mounting of **Legris air fitting** (available on Moodle by Mr Jason Young)





Preparation of CDR report

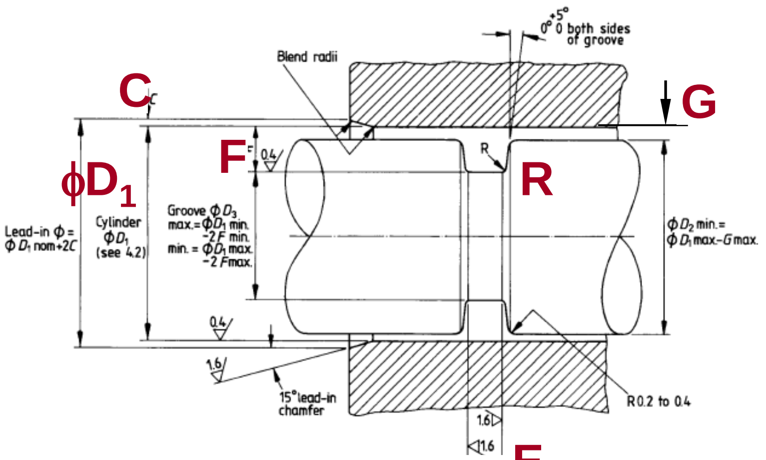
Team working and individual contribution (1 page per group)

- Present a **summary of team working and individual contributions** to project work and CDR submission in a tabular form
  - Group work and **identifiable individual contribution** to CDR submission, e.g.
    - Solidworks modelling, drawings (use name convention with Initials)
    - Calculations (spreadsheet or hand-written)
    - GA, detail drawings and process sheets
    - Cutting list, Part list for 3D printing and manufacturing plan
    - Writing of report or sections
    - Organisation of CDR files, data and folders and CDR submission
    - Contribution to any other aspects of the Group D&M project
  - Issues for your Design Tutor's attention

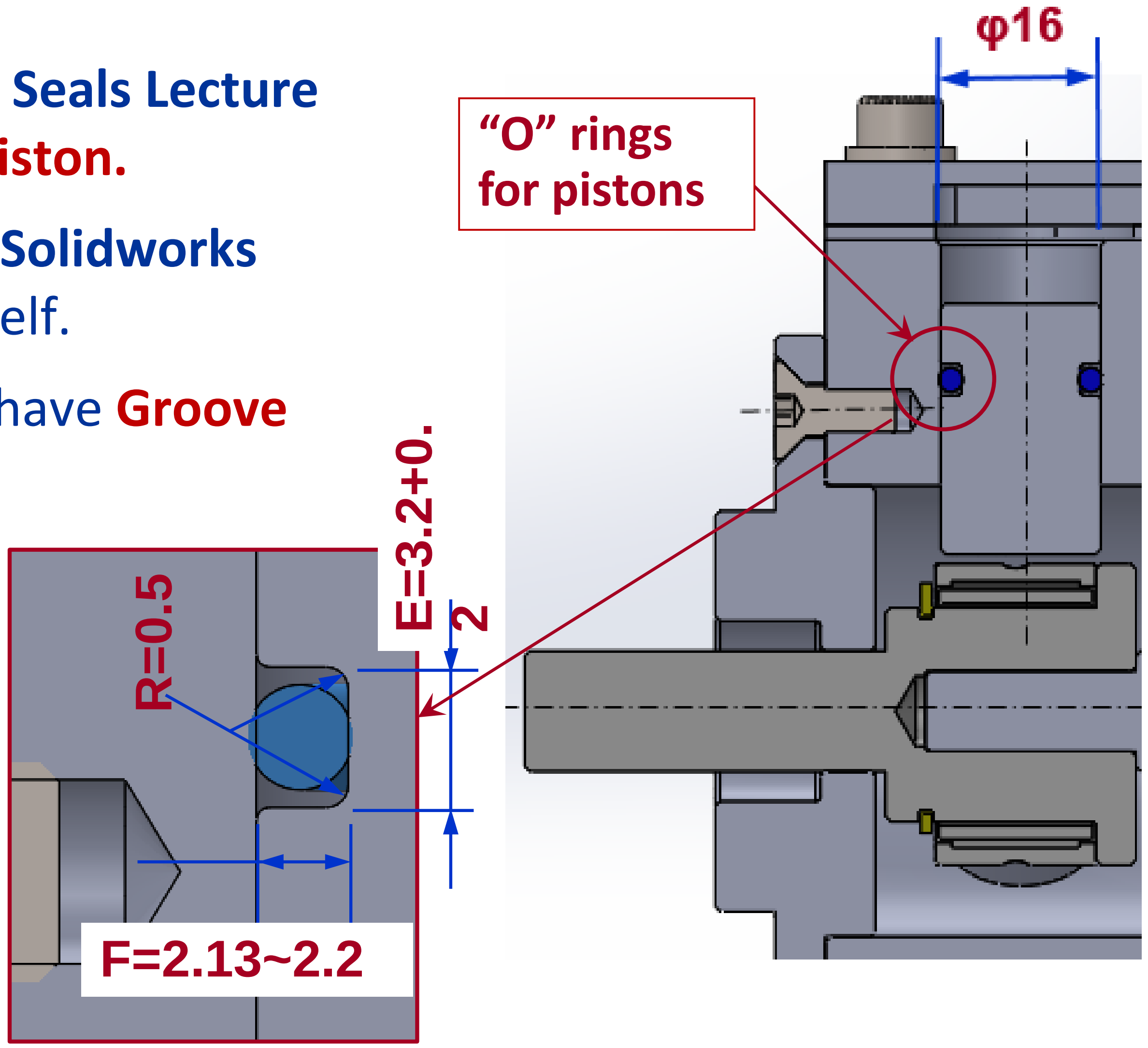
Sample solutions of practical design

Select suitable "O" rings & Groove dimensions (based on BS 4518)

- **"O" ring grooves** cut in piston (shaft).
- From **BS4518 Table 1** (available on **Moodle and Seals Lecture handbook**), **0116-24** is suitable for a **ϕ16 mm piston.**
- **0116-24 "O" rings CAD model** is available from **Solidworks Toobox BSI part library** or you can create yourself.
- From **BS4518 Table 4, 0116-24** "O" ring should have **Groove dimensions below**.

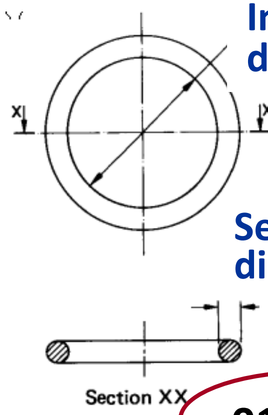


Groove in piston



Sample solutions of practical design

Select a suitable "O" ring Groove dimensions (Groove in piston)



0116-24

B = ϕ 11.6 mm
A = ϕ 2.4 mm

Table 1 — Dimensions of "O"-rings (see Figure 1) and related nominal housing diameters for diametral sealing (see Figure 2)

All dimensions in millimetres

"O"-ring ref. no (see note)	"O"-ring dimensions				Nominal housing dimensions (see Figure 2 and 4.1)	
	Internal diameter B	Internal diameter tolerance	Section diameter A	Section diameter tolerance	Shaft diameter d_1	Cylinder diameter D_1
0031-16	3.1		1.6		3.5	6
0041-16	4.1		1.6		4.5	7
0096-24[a]	9.6		2.4		10[b]	14
0106-24[a]	10.6		2.4		11	15
0116-24[a]	11.6		2.4		12[b]	16[b]
0126-24[a]	12.6		2.4		13	17
0136-24[a]	13.6	± 0.2	2.4	± 0.08	14[b]	18

Table 4 Groove Dimensions for pneumatic applications

All dimensions in millimetres

"O"-ring ref. no.	Cross section diameter A	Radial depth F max.	Radial depth F min.	Groove width $E^{+0.2}_{0}$	Total diametral clearance G (max.)	Lead-in chamfer C	Max. radius R
0036-24 to 0176-24	2.4	2.20	2.13	3.2	0.14	0.6	0.5
0195-30 to 0445-30	3.0	2.77	2.70	4.0	0.15	0.7	1.0
0443-57 to 1443-57	5.7	5.38	5.22	7.5	0.18	1.0	1.0
1441-84 to 2491-84	8.4	7.96	7.75	11.0	0.20	1.2	1.0

"O" ring groove dimensions

Depth **F** = 2.13~2.20

Width **E** = 3.2+0.2

Clearance **Gmax** = 0.14

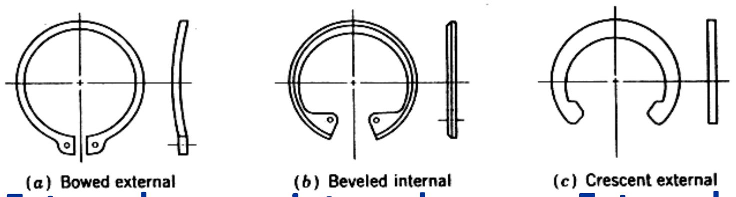
Chamfer **C** = 0.6

Radius **R** = 0.5

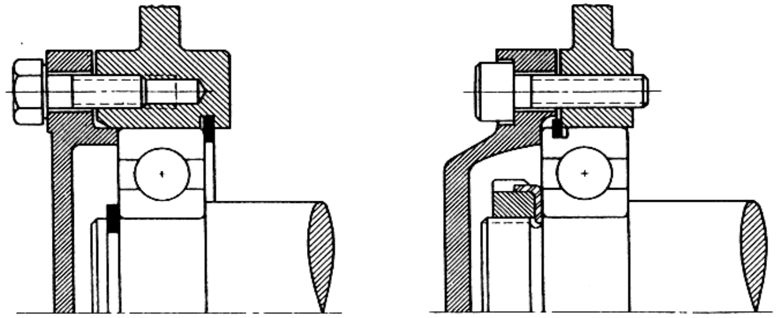
Sample solutions of practical design

Select suitable Circlips (Retaining rings) for axial location

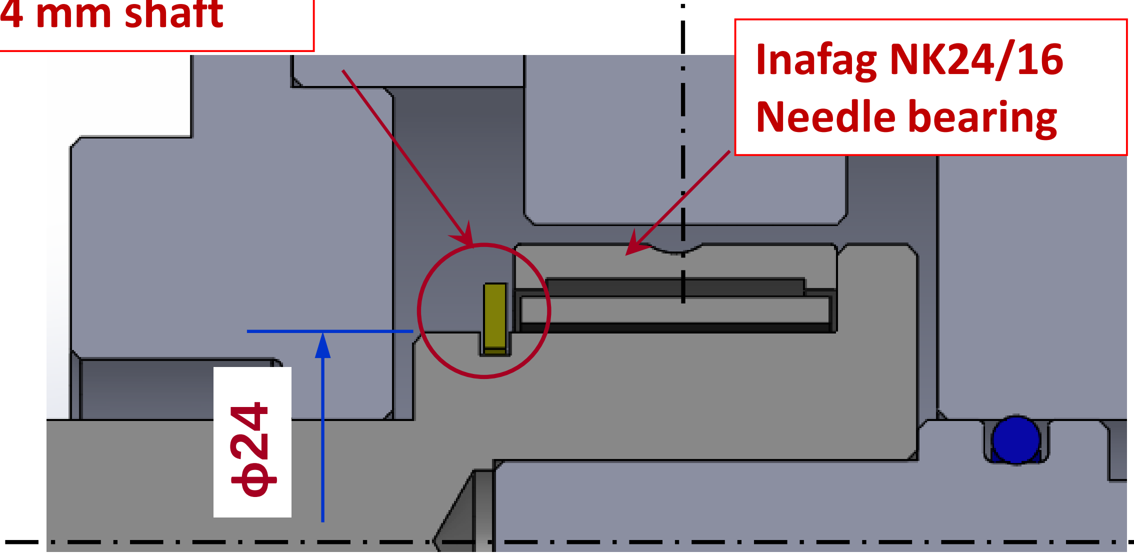
- **Circlips** used to provide the axial location of the **needle bearing (as shown in the figure)**.
- **Circlips** are a standard part available from different suppliers based on, e.g. **BS3673 prt4 & DIN471 (German standard)-D1400** (available on Moodle)
- **S024M external circlip** is suitable for **24 mm shaft.**
- **S024M external circlip CAD model** are available from **Solidworks Toobox BSI or DIN part library.**



External internal External



End cap, circlip & lock nut



Note: S024M & other sized circlips are available **in EA Workshop** or may be purchased from many suppliers.

Sample solutions of practical design

Circlips (Retaining rings) and Groove dimensions

S024M (S=24 mm) circlip design specs

Circlip details:

Diameter D = 22.2

Thickness T = 1.2

Groove details:

Diameter G = 22.9

Width W = 1.3

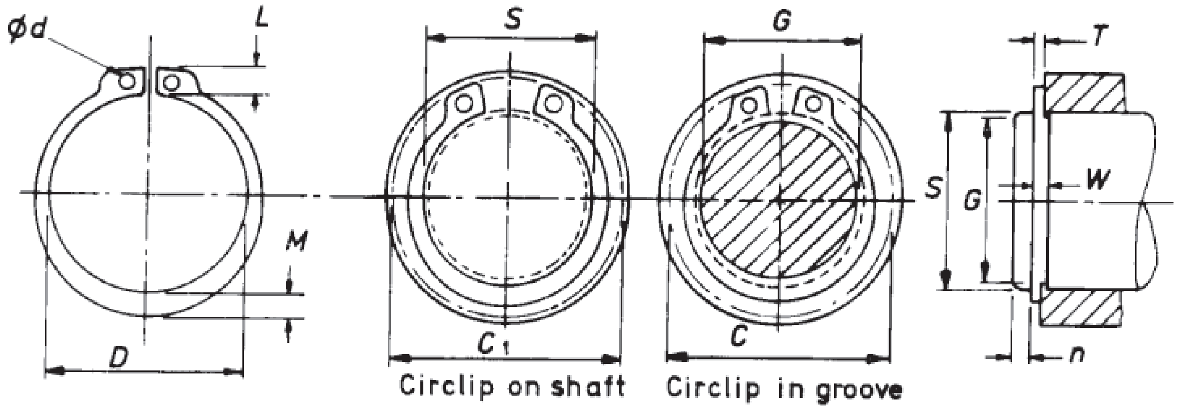


Table 1 — External series

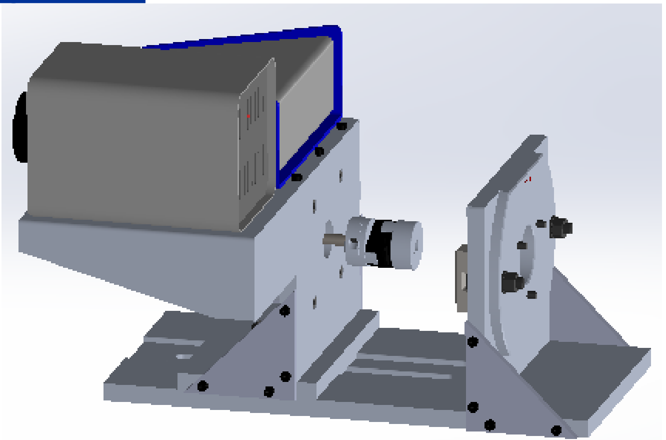
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Reference number of circlip	Shaft diameter	Groove details					Circlip details							Minimum external clearance	
		Diameter	Tolerance	Width	Tolerance	Edge margin min.	Diameter	Tolerance	Thickness	Tolerance	Beam approx.	Lug depth max.	Lug hole diameter min.	Fitted	During fitting
	S	G		W		n	D		T		M	L	d	C	C_1
S013M	13	12.4				0.9	11.9				2.0	3.4		19.2	20.8
S019M	19	18.0					17.5				2.5	3.9		25.8	27.8
S020M	20	19.0				1.50	18.5				2.6	4.0		27.0	29.0
S021M	21	20.0					19.5				2.7	4.1		28.2	30.2
S022M	22	21.0		1.3			20.5		1.2		2.8	4.2		29.4	31.4
S023M	23	22.0					21.5	+0.21 −0.42			2.9	4.3	2.0	30.6	32.6
S024M	24	22.9	0 −0.21		+0.14 0		22.2				3.0	4.4		31.7	33.8
S025M	25	23.9				1.70	23.2			0 −0.06	3.0	4.4		32.7	34.8
S026M	26	24.9					24.2				3.1	4.5		33.9	36.0

Note: In Table 1 tolerances for the circlip & groove are also given.

A few more items for CDR submission

- **Work effectively as a Group** on various components of CDR submission
- Bring your draft CDR report, GA & detail drawings, cutting list, etc, for your Tutor to review in **the next TWO Design sessions**
- Use SW models of NG24-16 needle bearing & Legris air fitting
- Use **SW Toolbox standard parts**, e.g. fasteners, circlips & set screws
- Make sure your Air Motor can be mounted on the **test rig**
- Compile SW models and files using the **template folders**

- **Back up all your files, Solidworks models, drawings, CDR report, regularly to avoid sudden loss of data**



- One Group member to submit your CDR on **Moodle** by **3:00pm, Friday, 9th December**

Feedback

- **Feedback** will include **completed mark sheet** (available on Moodle) and **feedback on design** in the **1st Design Session in the Spring semester**

  - **Satisfactory** - The deliverable was achieved on time to a **satisfactory standard** – you can proceed with your final design solution.
  - **Category 1 Deficiency** - The deliverable was not achieved or there was a **major deficiency**. The deficiency needs to be addressed before manufacturing sessions.
  - **Category 2 Deficiency** - The deliverable was achieved but there was a **minor deficiency** to be addressed before manufacturing sessions.
  - **Observation** - Items that are acceptable but **can be improved**.

- Additional feedback on the presentation, quality and clarity of contents of the CDR report and possible areas for improvement

Sample mark sheet

University of Nottingham UK | CHINA | MALAYSIA

MMME2044 Group Design and Make (Air Motor) CDR MARK SHEET

Design Group **Design Tutor**

	Elements for Consideration	Weight	Poor	Less than Acceptable	Acceptable	Good	Excellent	Outstanding	
Report	• Is the report structured clearly in compliance with CDR pro-forma? • Is the report written in a clear and concise manner? • Does the report draw clear conclusions to the questions by the LAP Board?	10	Poor construction. Spelling errors Poor grammar. Lack of detail	Poor construction Spelling errors. Poor grammar, some degree of details.	The report is clearly structured and written with adequate amount information in sections.	The report is clearly structured and concisely presented with conclusions drawn to the LAP's Board's questions. Good grammar. Well laid out with support of illustrations.	The report is clearly structured and concisely presented with clear conclusions drawn the LAP's Board questions. Clear concise. Good grammar. Well laid out good diagrams and illustrations.	The report is clearly structured and concisely presented with convincing and quantifiable conclusions drawn to the LAP Board's questions. Clear concise. Good grammar. Well laid out. Good diagrams and illustrations. Executive report standard	
		Marks	0-39	40-49	50-59	60-69	70-79	80-100	
		Award							0
Engineering	• Will it work? • Are limits and fits appropriate? • Is there clearance for moving parts? • Can it be manufactured? • Can it be assembled? • Does it fit the test rig?	20	Completely unworkable few or no components selected	Would not work, poor concept, no consideration of assembly, poor choice of components.	Just meets the design intent. Probably would work with some changes	Meets the design intent and would work, good component selection, easy to assemble	Meets the design intent, good concept. Will work, good component selection, easy to assemble	Meets the design intent, excellent and novel concept. Will certainly work, good component selection. easy to assemble	
		Marks	0-39	40-49	50-59	60-69	70-79	80-100	
		Award							0
Calculations	• Power calculations • Forces and loads • Basic stresses • Are the calculations consistent with the Design?	15	Few or no calculations. Inappropriate assumptions, formulae & procedure	Calculations incomplete, major corrections and alterations required	Identified and completed some appropriate calculations, ... corrections and alterations ... Correct use of formulae.	Identified and completed, most calculations completely and correctly. Correct use of formulae. Did not clearly connect the outcomes to their design	Identified and completed, most calculations completely and correctly. Correct use of formulae. Mostly connected the outcomes to their design. SI units and appropriate numbers of decimal places and significant figures used.	All calculations complete and correct. Correct use of formulae. SI units and appropriate numbers of decimal places and significant figures used. Clearly related to design process. Easy to follow and verify	
		Marks	0-39	40-49	50-59	60-69	70-79	80-100	
		Award							0
Assembly Drawings	• Parts list – all parts identified with BOM balloons, all necessary bought in part details or standards quoted, materials and quantities identified? • Layout – sufficient views and sections – how is it assembled? • Does it meet the design intent? • Are limits, fits and tolerances correctly identified?	15	Incomplete parts list, materials not all correctly specified. Inadequate views required to convey the design intent	Incomplete parts list, materials not all correctly specified. Significantly more or larger views required to convey the design intent. Lacking or inappropriate ...	Complete parts list, correct ... materials specified, BOM ... more ... required to convey the design intent ... Scales specified	Complete parts list, correct numbers off, materials specified, BOM balloons. some views and sections to convey the design intent. Scales specified.	Complete parts list, correct numbers off, materials correctly specified, clear BOM balloons. good choice of views and sections to convey the design intent. Scales specified. Excellent standard of GA.	Complete parts list, correct numbers off, materials correctly specified, clear BOM balloons. Excellent choice of views and sections to convey the design intent. Scales specified. Professional standard of GAs.	
		Marks	0-39	40-49	50-59	60-69	70-79	80-100	
		Award							0
Detail drawing	• Are the drawings to BS8888? • Are the drawings complete – are enough details given to define parts? • Datum features established? • Are all dimensions and necessary tolerances defined?	15	Datums not established. Few, incorrect or no dimensions. Inadequate choice of views.	Datums established. Dimensions ... poorly specified ... of views.	Datums established. Most dimensions correctly specified. Adequate choice of views. Drawings in accordance with BS8888	Datums established. All dimensions correctly and required tolerances specified. Good choice of views. Drawings in accordance with BS8888	Datums established. All dimensions and tolerances correctly specified. Excellent choice of views. Drawings in accordance with BS8888	Datums established. All dimensions and tolerances correctly specified. Excellent choice of views and correct use of cross hatching. Drawings in accordance with BS8888	
		Marks	0-39	40-49	50-59	60-69	70-79	80-100	
		Award							0
Manufacturing plan, cutting and process Sheets	• Do the process sheets define a sensible set of steps to manufacture the given parts? • Cutting list – is the cutting list clearly specified? • Part list for 3D printing – are all details given? • Is the Manufacturing plan realistic?	10	Little or no manufacturing information. Inadequate cutting list	Some manufacturing information missing. Cutting list only partially complete	Parts could probably be manufactured from the information provided, but the information could be clearer. Cutting List acceptable. Little consideration of manufacturing plan.	Parts could be manufactured without further reference. There is a correct Cutting List and Part list for 3D printing. Some consideration of manufacturing plan	Parts could be manufactured in the most efficient manner without reference. Correct Cutting List and Part List for 3D printing. Manufacturing plan looks realistic.	Parts could be manufactured in the most efficient manner without reference, with minimum waste. Correct Cutting List and Part List for 3D printing. Manufacturing plan demonstrates confidence in the outcome of the make stage of the project.	
		Marks	0-39	40-49	50-59	60-69	70-79	80-100	
		Award							0
Engagement	• Attendance to Design Sessions and active participation in discussions • Sufficient progress shown in PDR submission • Active engagement and communication with tutor • Evidence of effective teaming working individual contribution • All deadlines met • Peer assessment on Moodle and Tutor	15	No or very few attendance to Design sessions. Little evidence of any teaming working or individual contribution. No engagement or communication with Design Tutor. Lack of communication with other Group members	A few attendances to Design sessions. Lack of evidence of teaming working and individual contribution. Lack of contribution to PDR and CDR submission. Engagement with Design Tutor is minimum. Lack of communication with other Group members or Design Tutors.	Attendances to Design sessions. There is an effort or evidence of teaming working and individual contribution. Contribution to PDR and CDR submission. Adequate engagement with Design Tutor. Adequate level of communication with other Group members or Design Tutors.	Attendances to most Design sessions except ECs. There is a good effort toward effective teaming working and individual contribution of various aspects of work. Clear contribution to PDR and CDR submission. Active engagement with Design Tutor. Good level of communication with other Group members or Design Tutors. A working plan for team working	Attendances to all Design sessions except ECs. Excellent effort for effective teaming working and individual contribution of various aspects of work. Clear contribution to PDR and CDR submission. Active engagement with Design Tutor. Excellent level of communication with other Group members or Design Tutors. A working plan for efficient team working. Most deadlines met.	Attendances to all Design sessions except ECs. Excellent effort for effective teaming working and individual contribution to all aspects of work. Clear contribution to PDR and CDR submission. Active engagement with Design Tutor. Excellent level of communication with other Group members or Design Tutors. A working plan for efficient team works. All deadlines met.	
		Marks	0-39	40-49	50-59	60-69	70-79	80-100	
		Award							0
	Total	100							0