MODULE 4C4 - 2006 - CRIB

1

(a) * Design a cross cut shredder for the domestic market.
↓
* Design a means of cutting or destroying documents so that no information can be obtained from them.
↓
* Devise a means of making information unobtainable from documents prior to disposal
↓
* Devise an approach to searing information.

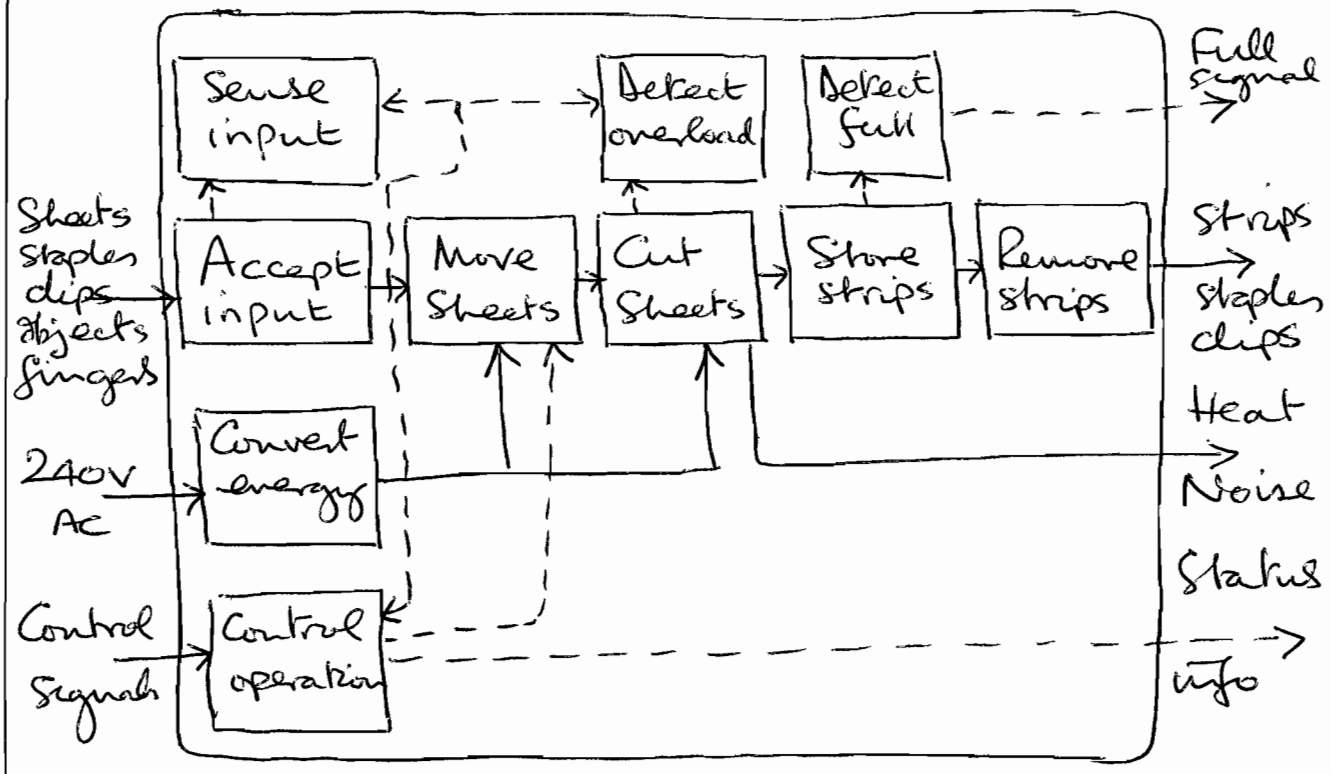
"Design a means of cutting documents into strips." [10%]

(b)
1 Cut into narrow strips (D)
2 High rate of cutting (W)
3 High sheet feed rate (W)
4 Easy operation (W)
5 Meet all safety requirements (D)
6 Compact (W)
7 Large storage capacity (W)
8 Low price (W)
9 Good ergonomics (D)
10 Appealing aesthetics (D)
11 Easy production and assembly (D)
12 Capacity to cope with staples and paperclips (W)
13 Capacity to cope with "other" objects (W)
14 Easy to transport (D)
15 No maintenance (D)
16 Life of 3 years (W)
17 Capable of being recycled (W)
18 Run off 240v AC (D) [10%]

Note: Only 10 required

(c) Overall function: "Cut documents"

Sub-functions and function structure:



[30%]

(d)

Price	3
Overall size	2
Feed Capacity	3
Bin Capacity	2
Shredding Speed	1
Accept staples	2
Durability	1

Criteria

Weightings

Value Scale : 5 very good (ideal)
4
3
2
1 just acceptable

Evaluation Chart (absolute)

Criteria ↓	wt	S1		S2		S3	
Price	3	3	9	2	6	5	15
Feed Capacity	3	2	6	4	(12)	2	6
Overall size	2	4	8	2	4	5	10
Bin capacity	2	3	6	5	(10)	2	4
Accept staples (and P/clips)	2	3	6	5	(10)	0	0
Shredding Speed	1	4	4	5	5	3	3
Durability	1	4	4	5	5	3	3
			43		(52)		41

Ideal score = 70 (100%)

61% 74% 59%

↑ Main Competitor

(e) Target selling features: [40%]

* Good quality, high capacity shredder
* Accept staples (possibly not paper clips)
* Safe, reliable, ergonomic, aesthetic
* Recyclable

Note: Shredding Speed and overall size not critical features [10%]

2 (a) The overall function is "Retain water".

Process function structure

Problems

Misplaced → Collect sealing sections

Transport sections

damage seals → Unload sections

Jam / Seals perished → Install sections

Many Potential leakage paths → Apply vertical load

Flood warning

Underneath / Verticals / horizontals → Check sealing

Seal leakages

During flooding

Sand bags / Silicone seal / plastic sheeting → Remove sections

Load sections

After flooding

As above → Transport sections

Unload sections

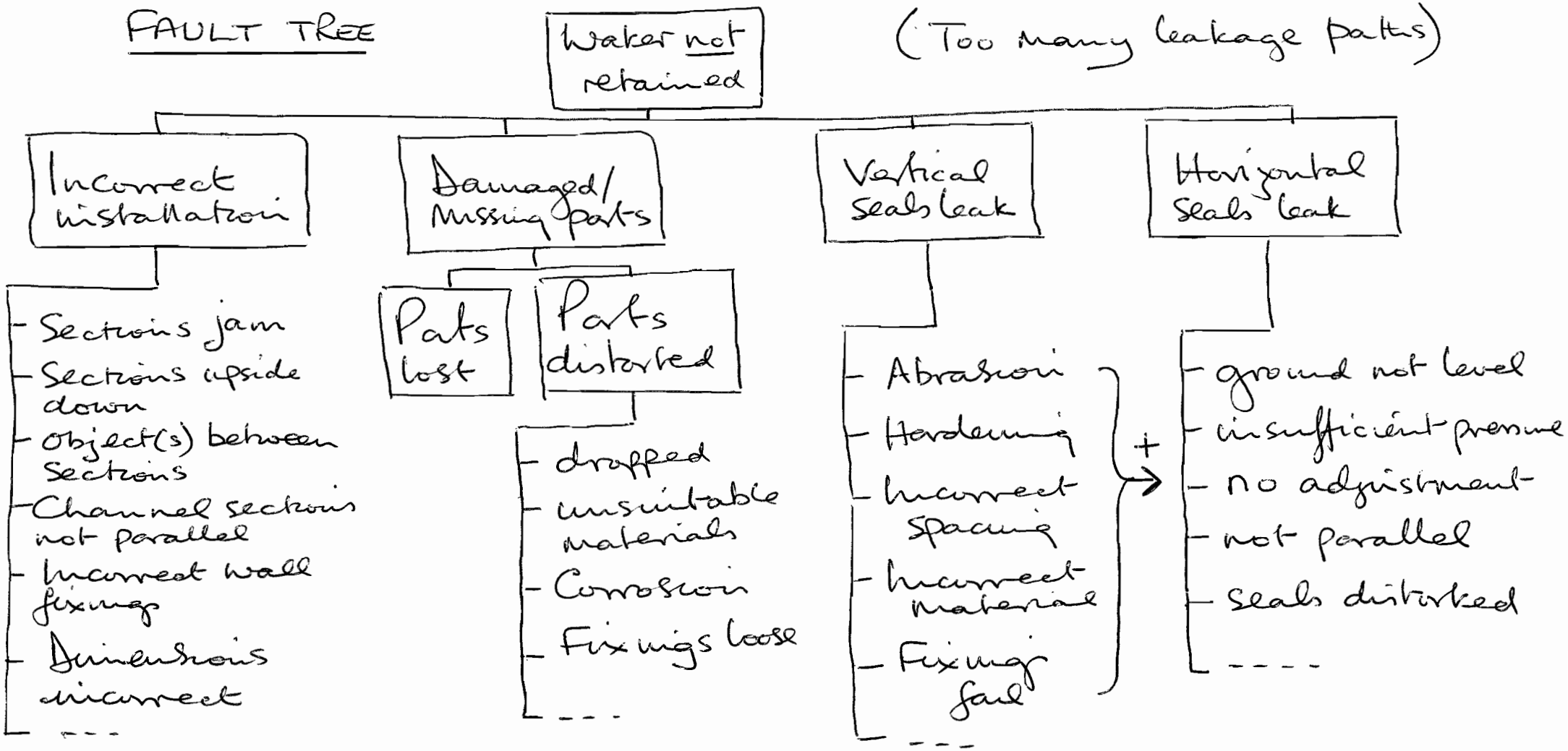
Clean Sections

Store Sections

Function of each Main function Carrier could also be considered, i.e.

* Wall
* Channel sections
* Wall attachments
* Vertical Seals
* box sections
* horizontal seals

FAULT TREE

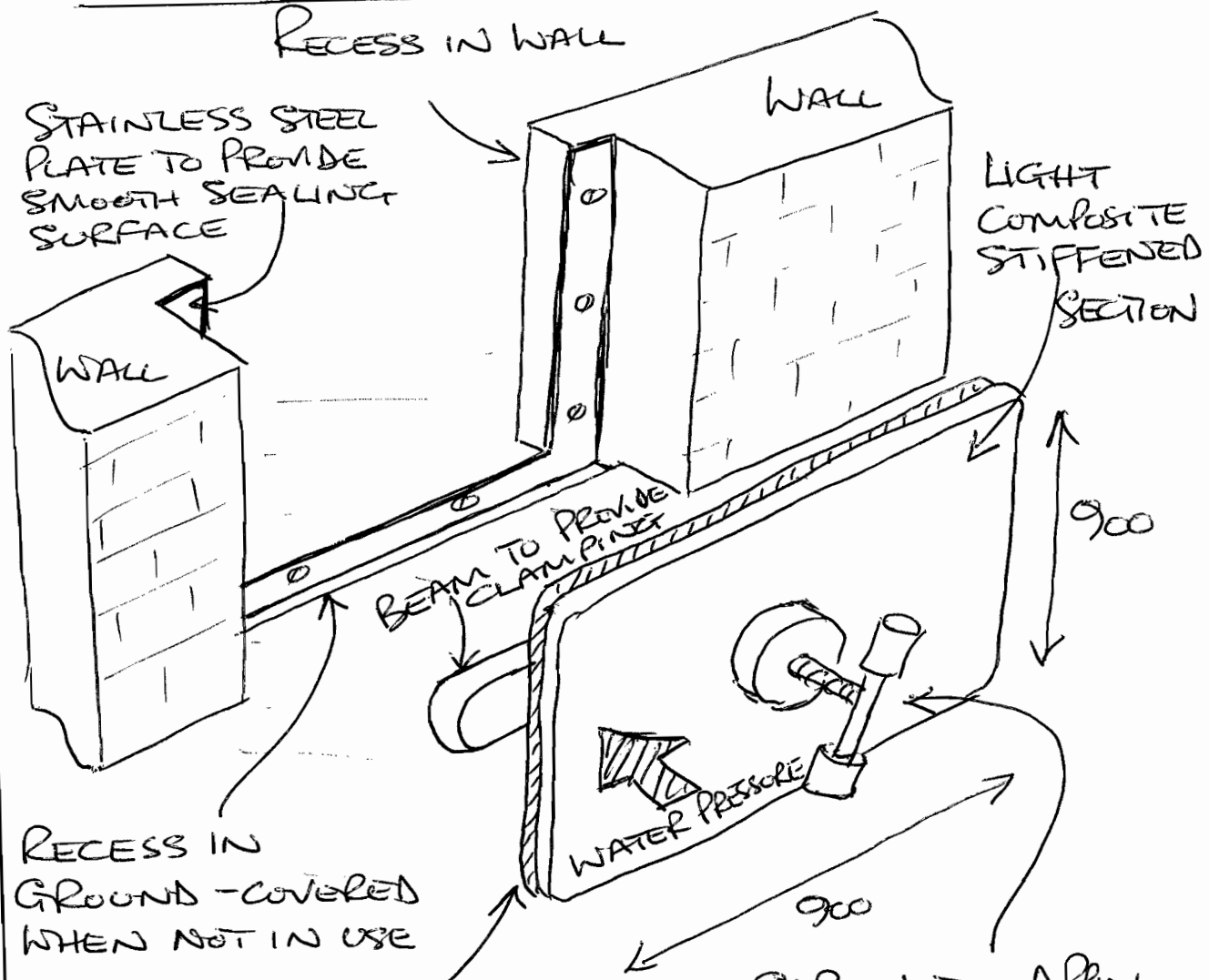

Water not retained
(Too many leakage paths)
Incorrect installation
Damaged/ Missing parts
Vertical seals leak
Horizontal seals leak
- Sections jam
- Sections upside down
- Object(s) between Sections
- Channel sections not parallel
- Incorrect wall fixings
- Dimensions incorrect
- ---
Parts lost
Parts distorted
- dropped
- unsuitable materials
- Corrosion
- Fixings loose
- ---
- Abrasion
- Hardening
- Incorrect spacing
- Incorrect material
- Fixing fail
- ---
+
- ground not level
- insufficient pressure
- no adjustment
- not parallel
- seals distorted
- ----

(b) The main problem is large number of potential leakage paths; so the aim should be to minimise the leakage paths and use the principle of self-help (self-reinforcing)

Keep seals on section to be fitted so that they are not adversely affected by the weather.

Make section light so easily shoved (and fitted) by householder.

Possible design:



NOTE: SEALING ↑ ; ACCESS ↓

[50%]

3 (a) $h_{roof} = 4 h_{wall}$

Total heat flux q = wall flux + roof flux

$\therefore q = h_{wall} \Delta T (2 \times 5wz + 2dz) + h_{roof} \Delta T (5dw)$

$$\underline{q = h_{wall} \Delta T (10wz + 2dz + 20dw)}$$

↖ Minimise subject to:

$$600 - wdz \leq 0$$

and $-w < 0$; $-d < 0$; $-z < 0$.

h and ΔT are parameters

w, d and z are design variables [30%]

(b) (i) $z = 6m$ and $wdz = 600 m^3$

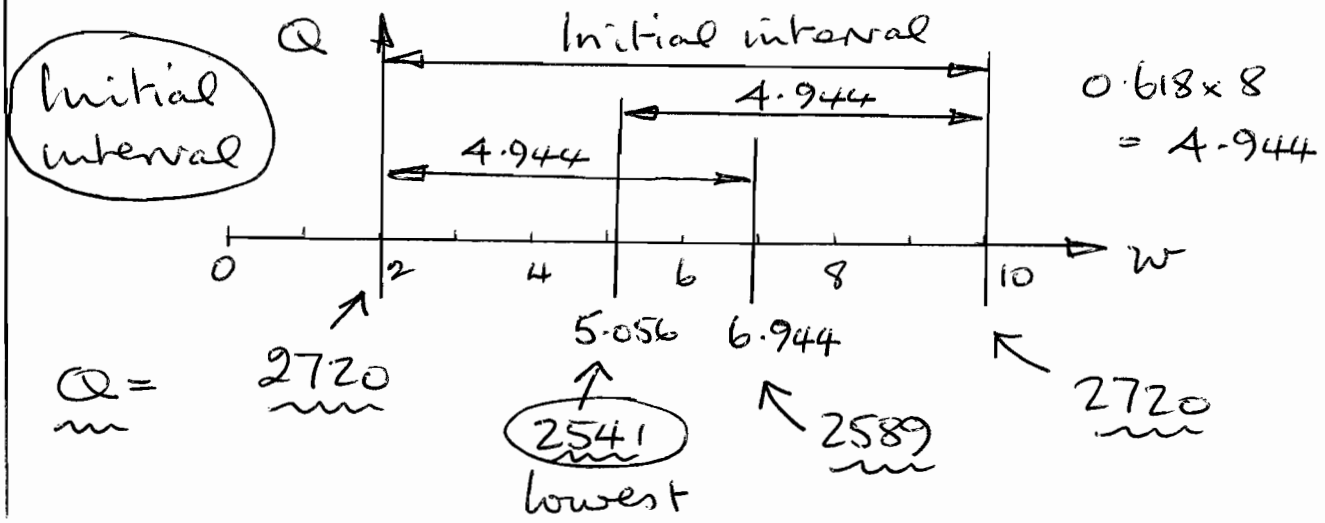
$\therefore wd = 100 m^2$ and $d = \frac{100}{w}$

The above expression for q can be simplified to:

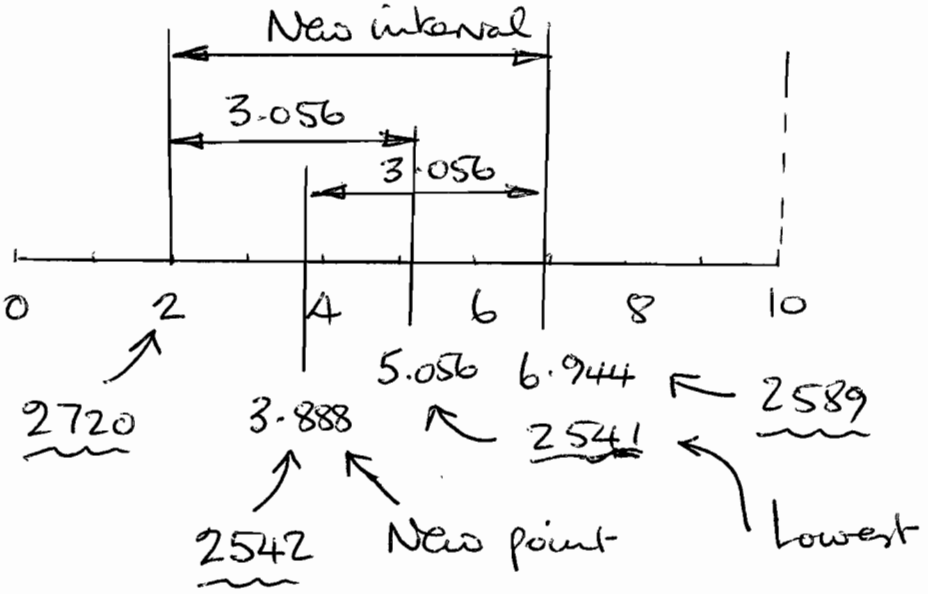
$$q = h_{wall} \Delta T \overbrace{\left(60w + \frac{1200}{w} + 2000\right)}^{Q}$$

[10%]

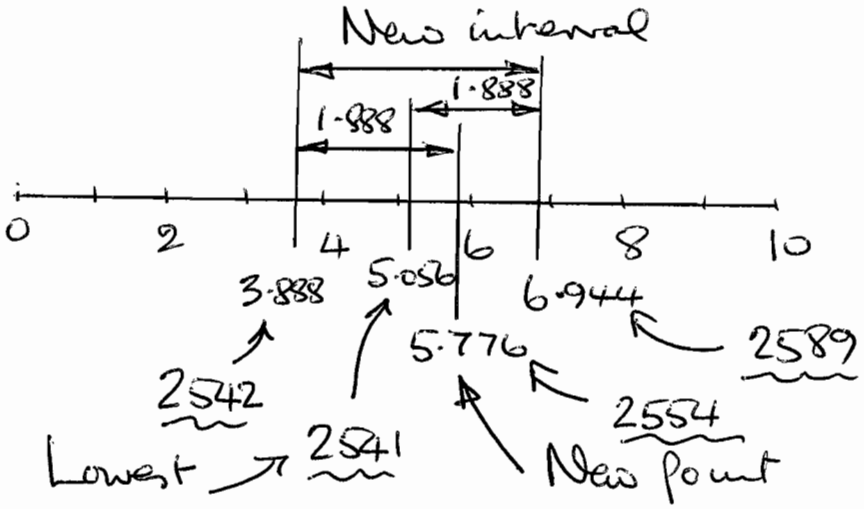
(ii) Data Book, page 3: Golden Section Ratio = 0.618



Step 1



Step 2



[30%]

Hence w must lie in the range $3.888 < w < 5.776$

(iii) First order conditions: $\frac{dQ}{dw} = 0$ at min.

$\therefore \frac{dQ}{dw} = 60 - \frac{1200}{w^2} = 0 \Rightarrow w = \underline{4.47\,m}$

and $d = \frac{100}{w} - \frac{100}{4.47} = \underline{22.37\,m}$ and $z = \underline{6.00\,m}$

[10%]

(c) Constraints: $g_1(z) = z - z_{max} \leq 0$

$g_2(w,d,z) = 600 - wdz \leq 0$

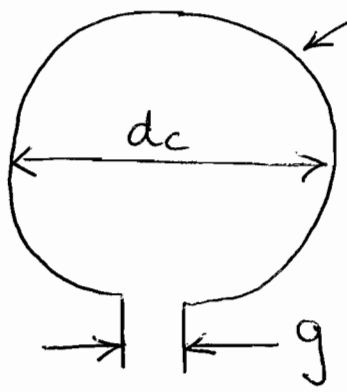
Data Book, Page 5: Barrier function is

$f(\mu, w, d, z) = 10wz + 2dz + 20dw - \mu \sum_{i=1} \frac{1}{g_i(w,d,z)}$

$= 10wz + 2dz + 20dw - \mu\left(\frac{1}{z - z_{max}} + \frac{1}{600 - wdz}\right)$

[20%]

4 (a)



circumference $= \pi d_c = c$

Change in d_c caused by closing gap g

$$c - g = \pi(d_c - \delta d_c) = c - \pi\delta d_c$$

$$\therefore \underline{\delta d_c = g/\pi}$$

Clip diameter when gap closed is

$$d_c - \delta d_c = (d_c - g/\pi) \quad \text{↲}$$

Interference $i = d_p - (d_c - g/\pi)$

$$\therefore \underline{\underline{i = d_p - d_c + g/\pi}} \qquad [1\text{d}]$$

(b) Nominal: $d_p = 27.2$ mm; $d_c = 27.4$ mm; $g = 2.0$ mm

$$i_{nom} = 27.2 - 27.4 + \frac{2}{\pi} = 0.437\text{mm}$$

$$\therefore SF_{nom} = \frac{0.437}{0.3} = \underline{\underline{1.46}} \leftarrow \text{ok}$$

Req'd interference ↗

Worst case: $d_p = 27.1$ mm; $d_c = 27.5$mm; $g = 1.5$mm

$$i_{wc} = 27.1 - 27.5 + \frac{1.5}{\pi} = 0.078$$

$$\therefore SF_{wc} = \frac{0.078}{0.3} = \underline{\underline{0.26}} \leftarrow \text{Not ok.} \quad [2\text{d}]$$

(c) Safety margin = (Achievable interference) − (Required interference)

$$m = (d_p - d_c + g/\pi) - (0.3)$$

Data Book, page 6:

$$y = a_1x_1 + a_2x_2 + a_3x_3 + a_4 = m$$

where $a_1 = 1$, $a_2 = -1$, $a_3 = \frac{1}{\pi}$, $a_4 = -0.3$

$$\mu_m = \mu_p - \mu_c + \frac{\mu_g}{\pi} - 0.3$$

and $$\sigma_m^2 = \sigma_p^2 + \sigma_c^2 + \left(\frac{\sigma_g}{\pi}\right)^2$$

$$\mu_m = 27.2 - 27.4 + \frac{2.0}{\pi} - 0.3 = \underline{0.137}$$

$$\sigma_m^2 = \left(\frac{0.1}{3}\right)^2 + \left(\frac{0.1}{3}\right)^2 + \left(\frac{0.5}{3\pi}\right)^2 = 0.005$$

$$\therefore \underline{\sigma_m = 0.071}$$

Data Book, page 5:

$$z = \frac{x - \mu}{\sigma} = \frac{m - \mu_m}{\sigma_m}$$

$$P(m<0) = P\left(z < -\frac{\mu_m}{\sigma_m}\right) \text{ where } \frac{\mu_m}{\sigma_m} = \frac{0.137}{0.071} = \underline{1.93}$$

$$= 1 - P(z < 1.93)$$

From the table $= 1 - 0.9723 \Rightarrow \underline{\underline{2.8\%}}$ [40%]

(c) The design can easily be improved by increasing the gap - but not by too much [10%]

(d) Other failure modes include:
* Impossible to assemble ($d_p > d_c$)
* Plastic deformation of the clamp
* Too much play below clamp in seat tube
* Yield or failure of the bolt lugs. [20%]