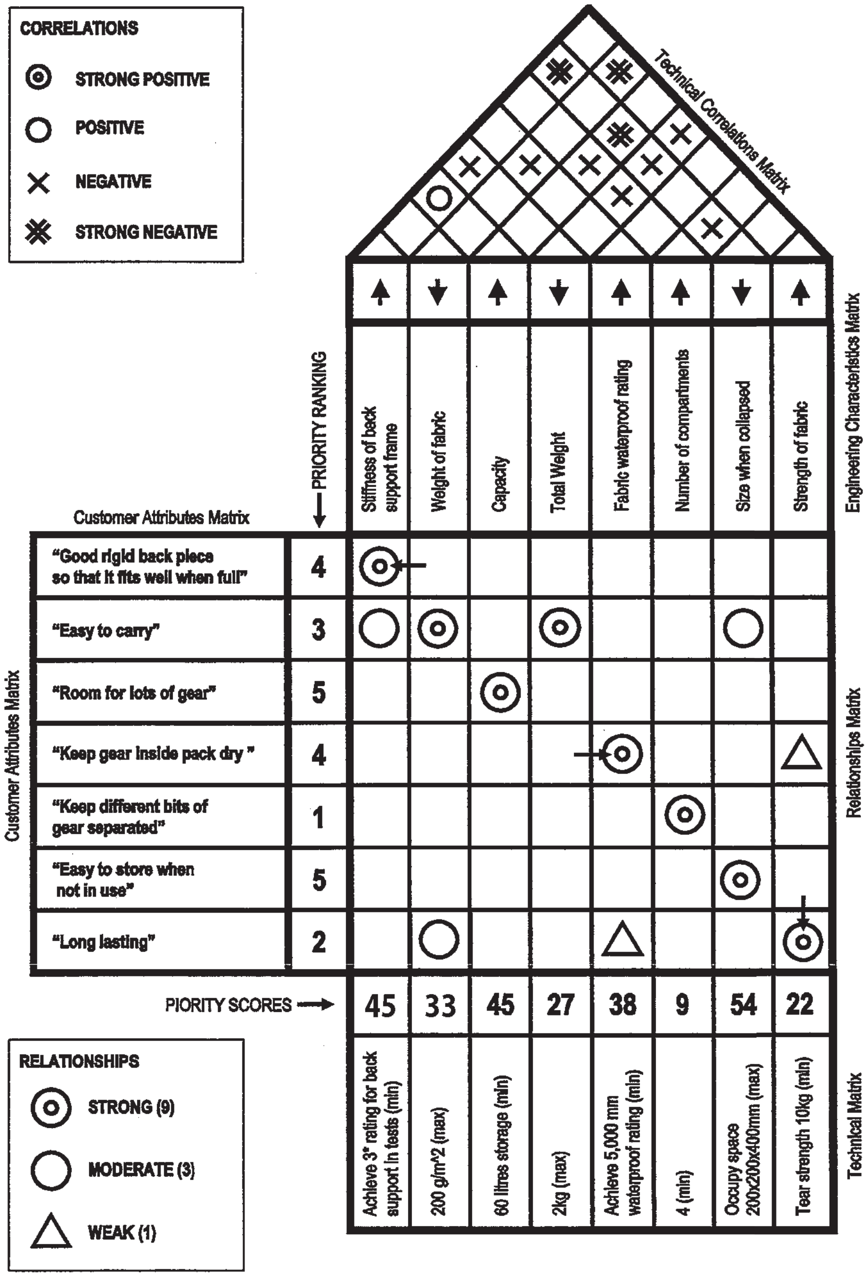
1a) From the summary notes: QFD (the *House of Quality*) is a tool intended to assist a development team in focussing on the needs of their customers. It helps to transform customer requirements (the voice of the customer) into engineering characteristics (the voice of the designer). QFD provides a means of prioritising which aspects of the product demand the most attention, and it can help facilitate communication across organisational functions.

b, c and d Candidates' solutions should look like this:



The main features are (i) the diagonal of strong relationships in the relationships matrix, and (ii) the correlations matrix dominated by negative correlations. An obvious positive correlation is reducing the weight of the fabric and reducing the total weight of the pack.

e) None of the engineering characteristics by themselves pose a significant design challenge, but satisfying two negatively correlated engineering characteristics does. Consequently, the main design challenges to address are likely to be where there are strong negative correlations:

1. The requirement for a large load capacity whilst being compact for storage
2. The requirement for a stiff back frame whilst being compact for storage
3. Keeping the weight down whilst exhibiting good strength.

Of these two, the first two are likely to be the most important because they both relate to two high-scoring engineering characteristics (scores of 45 and 54). Possible design solutions might involve, articulation of the back support frame, the use of compression straps, using removable sections… (Various creative methods might be used here, especially SCAMMPERR.)

f) The task clarification checklist suggests the following three top-level categories: operation, maintenance and disposal. Customer attributes might therefore include: reasonable cost, attractive appearance, easy cleaning, high visibility, easy opening and closing (with gloves), compatible with standard equipment, convenient for air travel (stowable straps), environmentally friendly materials (both for production and recycling), etc.

g) From the summary notes:

The potential benefits of QFD can be briefly summarised as follows:

- Encourages cross-functional teamwork throughout the product development process, encouraging communication and cooperation
- provides a mechanism for increasing the use of marketing inputs
- Focuses the development team's minds on what they don't know
- Focuses on customer needs, not product features
- Prevents wild unqualified assumptions
- Ensures that a wide range of issues are considered, including customer requirements, technical characteristics and competitive products.

The potential drawbacks of QFD can be briefly summarised as follows:

- Requires a cross functional team, including, for example, representatives from marketing, engineering and manufacturing
- Can be exceedingly complex, time consuming and tedious
- Can be too analytical - a numerical answer can be treated as a 'right' answer
- Requires some training and strong facilitation initially
- There are many variants of QFD, each with their own terminology
- There is the risk that attention is devoted not to serving the customer, but to serving the matrices.

Examiner's comment:

This was a popular question, with most candidates attempting it and doing very well. The only section that most candidates did poorly on was section "e", where proper justification was seldom given and design solutions were often missing or grossly incomplete. Some candidates failed to specify customer attributes that were independent of engineering characteristics. The candidates generally demonstrated a very good understanding of the QFD process despite it not having been examined previously. Those candidates who linked the different sections of the QFD chart together to prioritise design challenges scored very highly.

2a) For example:

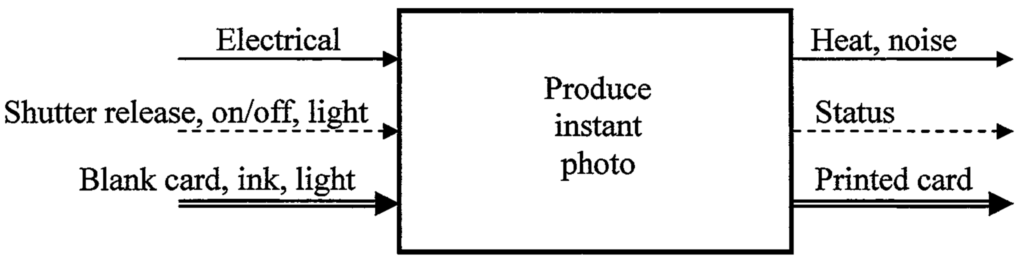
D/W	Wt	REQUIREMENTS
		GEOMETRY
W	H	• Fit the adult hand well (consult anthropometric charts)
W	M	• Hold cards of a useful size (>6x4 cm)
W	M	• Be lightweight (<500g)
		MATERIAL
D		• All external materials to be light-tight
		SAFETY
D		• No loose parts during use
D		• Conform to international safety standards for consumer electrical products
		ERGONOMICS
W	H	• Offer point-and-shoot convenience (minimal manual settings)
W	H	• Permit easy loading of card packs
		QUALITY CONTROL
D		• All devices to be tested prior to packaging
D		• Approved third party components (card, ink, cells) to be tested regularly
		ASSEMBLY
D		• Assembly and testing in Class K clean room (for sensor)
		STORAGE
W	M	• Retain power between events (e.g. through auto-power-off features)

D/W	Wt	REQUIREMENTS
		OPERATION
D		• Permit rapid shooting (>1 image every 10 seconds)
W	H	• Dispense smudge resistant images
D		• Work in low light (with or without flash)
D		• Provide accurate image framing preview (either electronic or optical)
D		• Operate effectively in different environmental conditions (for card handling)
		MAINTENANCE
W	M	• Hold enough cards for convenient use (>24 cards at once)
W	M	• Hold enough ink for >24 prints at once
W	M	• Be self-powered for > 24 shots
D		• Use standard and commonly available electric cells (AA or AAA)
W	H	• No maintenance should be required within warranty period (3 years)
D		• Refillable with additional card, ink and cells
		COSTS
W	H	• Unit cost less than £100
W	M	• Total running cost less than £1 per image

Any sensible collection of ten sections of requirements could gain full marks, but evidence of the following points should be demonstrated:

- Adopting a clear structure
- Quantifying whenever possible
- Identifying demands and wishes

b) An overall function structure for the device might be as follows (with energy, signals and materials considered):

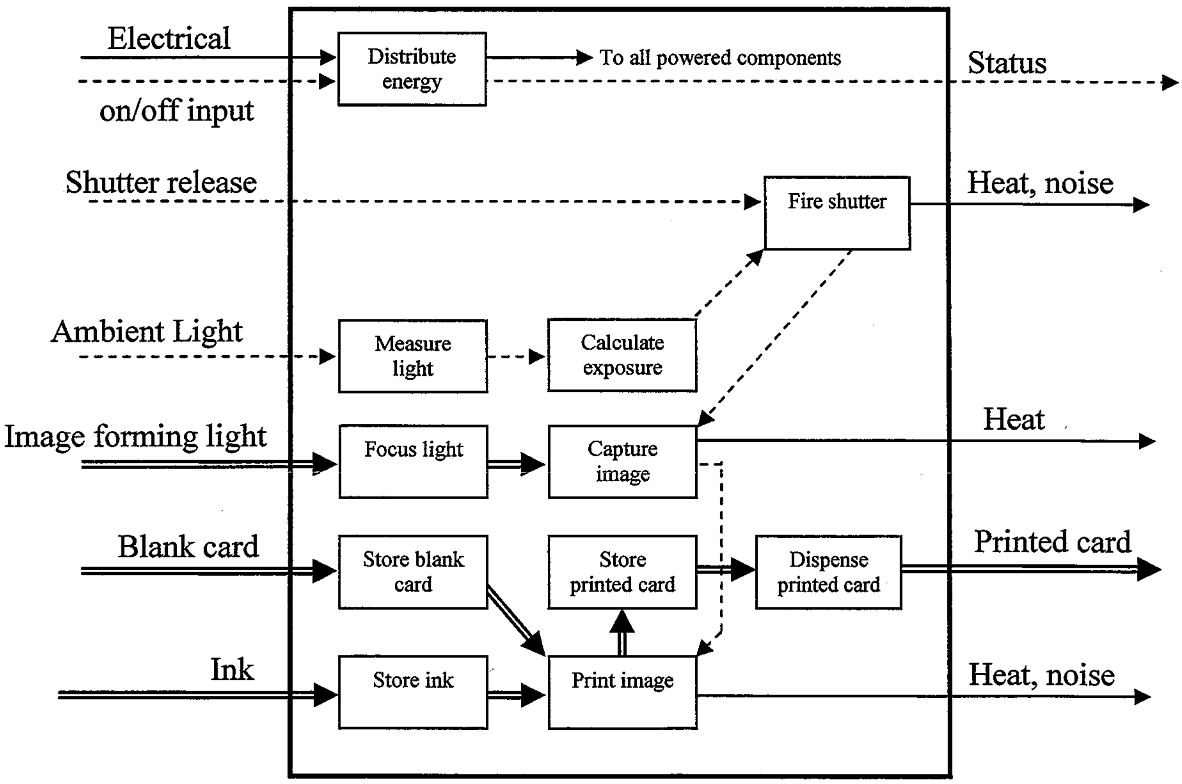


c) For example:

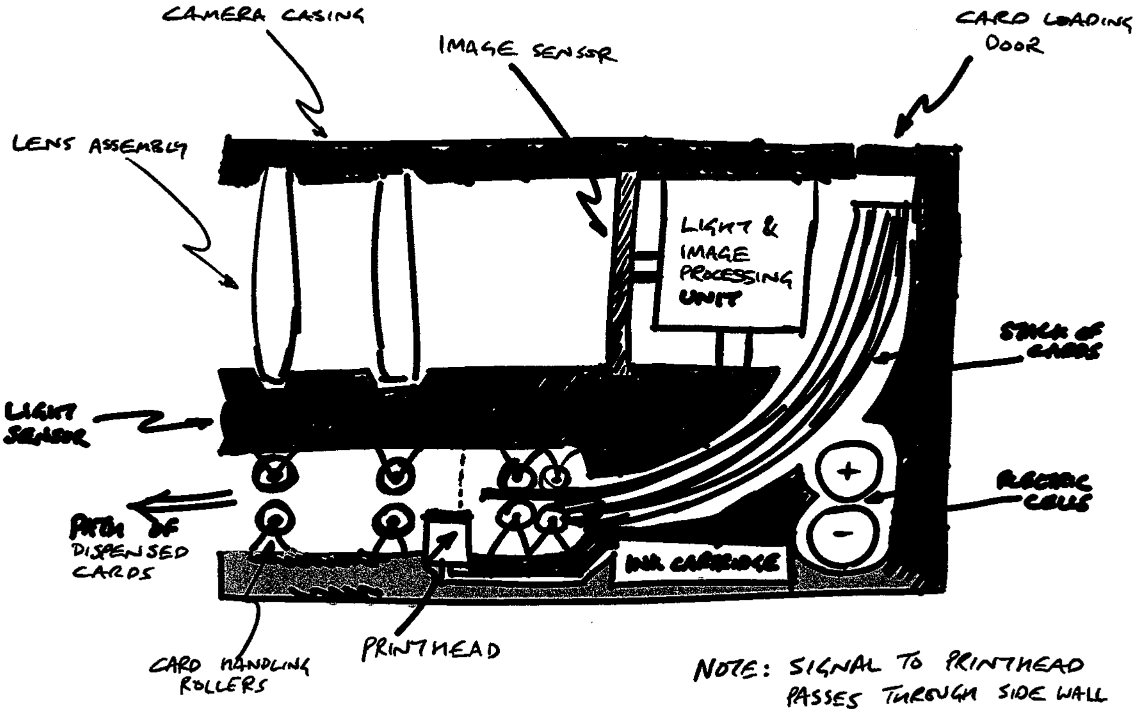
1. Store blank card
2. Store ink
3. Measure light
4. Focus light
5. Process shutter release input
6. Calculate exposure
7. Operate shutter
8. Capture image
9. Process image
10. Print card
11. Store printed card (drying time) if necessary
12. Dispense printed card
13. Indicate status (e.g. ready to shoot, no/off, etc)
14. Reset shutter
15. Display ink/power levels

Any sensible collection of ten sub-functions could gain full marks but the handling of light, ink, card and user inputs is expected. The function structure should show the flow of energy, materials and signals between the sub-functions. The overall inputs and outputs should be essentially the same as section b. For example:

PRODUCE INSTANT PHOTO



d) Depending on the answers to parts a and c, typical concepts might include some of the features shown below:



e) The embodiment design checklist suggests the following three high level categories: Safety, Clarity and Simplicity. In addition, candidates might usefully include comments on the following issues:

1. Size and weight (for handling)
2. Primary orientation (for handling)
3. Balance (for handling)
4. Card preservation (flat or curved)
5. Ease of loading
    a. card,
    b. batteries,
    c. ink
6. Orientation of printed image (face up/down)
7. Ease of manufacture, assembly, storage
8. Relative location of components that require material to be transported between them (ink, card)
9. Relative location of components that require signals to be sent between them
10. Heat dissipation (as indicated in the function structure)
11. Integral and modular approaches

Examiner's comment:

This was a popular question, with most candidates attempting it but not doing very well (approximately one-third of candidates seemed to run out of time on this question). The requirements specification was often either left unquantified and unprioritised. The overall product function was generally well defined but the product function structures were often incomplete and confused. The design sketches were often very uninformative with very few candidates revealing how their design would perform the functions that they had established as important. This was partly because very few candidates revealed any internal arrangement of components.

3a) Reference notes section 9. Key issue is that designs must be proven to be fit for purpose. Validation – check against user need; verification – check against specification; and review – check design activities/evaluation activities.

b) There were a number of issues raised in the lectures that included:

1. Reference to risk management as a means to drive the design process through the identification of areas of high technical risk which could be investigated in preference to areas of low risk, i.e. potential 'show-stoppers' should be prototyped to test validity before routine design is completed.

2. General approach to define function, form, then the means of production, with reference to active risk assessment to identify potential technical and design process problems, and to define risk reduction priorities.

3. Reference to the rework model and the resulting need to maximise design quality and to identify (discover) rework in a timely manner.

4. General approach to seek to verify performance at earliest opportunity and to validate product performance, with reference to 'waterfall' model.

c) In both cases failures could arise from blockages in the device, prohibiting delivery or dilution., OR there may be a failure to release.

In concept A, there may be a metering failure OR lack of available drug (all used) OR incorrect storage etc.

In concept B, there may be a storage failure OR lack of available drug (all used) OR incorrect loading etc.

d) It is fundamentally difficult to conceive how the drug might be released with either concept using only the patient's breath. There would need to be some means to 'prime' the device, storing energy to enable release prior to inhalation, but without releasing the powder early.

Examiner's comment:

A reasonably popular question on the paper, addressing issues relating to risk management. Most candidates demonstrated good knowledge of verification and validation, and were able to describe a number of practical approaches to risk management. The fault trees constructed for the two inhaler systems were of variable quality, as was the discussion of the relative merits of each device. All candidates made some comment regarding the viability of a breath operated inhaler.

4a) Example is based on that in the notes for calculating a standard shaft/hole fit.

c = stemblock Ø – stem Ø

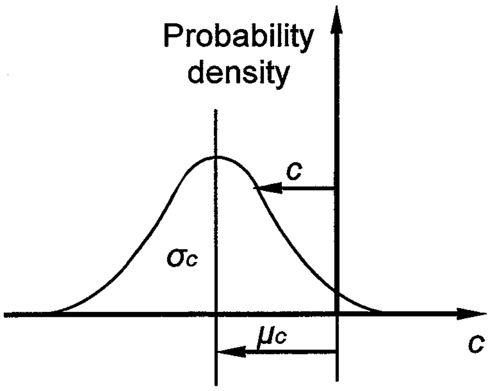
$\mu_c = 2.9 - 3.0 = -0.1\text{mm}$

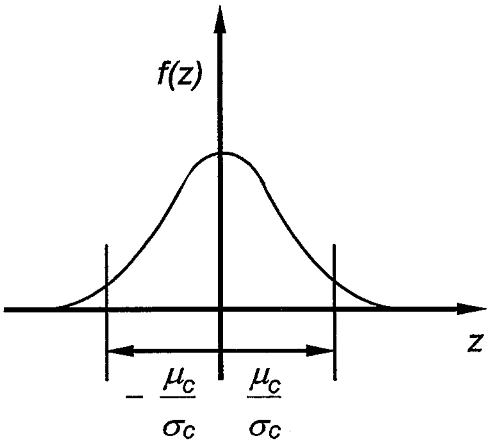
$\sigma_c = (0.05^2 + 0.05^2)^{1/2} = 0.07\text{mm}$

z = 1.4142

p(interference) = 0.9214 = 92%

p(clearance) = 0.0786 = 8%





stem	mean	3.00 mm
	deviation	0.05 mm
stemblock	mean	2.90 mm
	deviation	0.05 mm
c	mean	-0.10 mm
	deviation	0.07 mm
z		1.4142
p(z)	interference	**0.9214**
1-p(z)	clearance	0.0786

b)

stem	mean	3.00 mm	3.00 mm
	deviation	0.05 mm	0.05 mm
stemblock	mean	2.90 mm	**2.78** mm
	deviation	0.05 mm	0.05 mm
c	mean	-0.10 mm	-0.22 mm
	deviation	0.07 mm	0.07 mm
z		1.4142	3.1113
p(z)	interference	**0.9214**	**0.9991**
1-p(z)	clearance	0.0786	0.0009

p(interference) = 99.9% = 0.9990

z = 3.1113

$\mu_c = -0.22\text{mm}$

$\mu_{stemblock}$ **= 2.78mm**

c)

stem	mean	3.00 mm		3.00 mm
	deviation	0.05 mm		0.05 mm
stemblock	mean	2.78 mm		2.78 mm
	deviation	**0.03** mm		**0.03** mm
c	mean	-0.22 mm		-0.22 mm
	deviation	0.06 mm		0.06 mm
z		3.8061		-3.1141
p(z)	interference	0.9999	no fit	0.0009
1-p(z)	clearance	0.0001	interference	0.9991

$\sigma_{stemblock}$ will decrease, making likelihood of clearance fit negligible

For no fit, c < 0.4mm

p(no fit) = 0.1% = 0.0010

z = –3.1141

$\mu_c = -0.22\text{mm}$

$\sigma_c = 0.06\text{mm}$

$\sigma_{stemblock}$ $\mathbf{= (0.06^2 - 0.05^2)^{1/2} = 0.03mm}$

Examiner's comment:

A reasonably popular question, looking at the fit of an inhaler can stem into a moulded post. This was straightforward bookwork and most candidates made a very good attempt at the first two parts, many gaining the maximum marks. The majority of the candidates got the right answer for the last part, but ignored the fact that cans would not fit into the post for two reasons, namely being too large or too small. The latter problem was of negligible importance, but the candidates had to identify that this was the case, and prove it, before they gained maximum marks.