ENGINEERING TRIPOS PART IIA/IIB

Monday 6 May 2013 2 to 3.30

4C4

DESIGN METHODS

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments

STATIONERY REQUIREMENTS	SPECIAL REQUIREMENTS
Single-sided script paper	Engineering Data Book CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 A cycle D-lock comprising a lock barrel and a shackle is shown in Fig. 1. The lock barrel contains the lock mechanism and two circular holes to accept the cylindrical arms of the shackle. The nominal pitch between the centres of the two 10 mm holes in the lock barrel is 100 mm, the same as the nominal pitch between the centres of the two 9 mm diameter arms of the shackle. Manufacturing tolerances are such that there is a variation of ± 0.5 mm in the lock barrel centre-to-centre pitch and a variation of ± 0.1 mm in each hole diameter. The diameter of each shackle arm shows a variation of ± 0.1 mm and the variation in the arm centre-to-centre distance can be up to ± 2 mm.

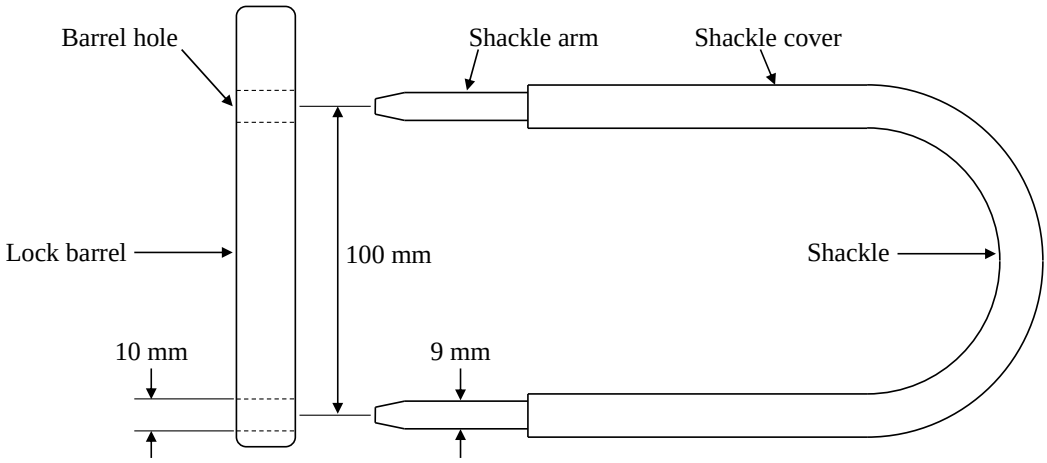

Fig. 1

(a) Define the meaning of the terms ‘safety-factor’ and ‘safety-margin’, and state how they may be applied to the shackle fitting through the lock barrel. [20%]

(b) Calculate the safety-factor for the shackle fitting through the barrel for the nominal and ‘worst case’ conditions. [20%]

(c) Assuming that all probability distributions are normal and that the range from minimum to maximum is equivalent to six standard deviations, calculate the percentage of shackles and barrels, randomly selected, that will not fit together:

(i) assuming no bending of the shackle;

(ii) assuming that bending of the shackle allows relative movement of the arm centres by up to 1 mm. [40%]

(d) What would be an appropriate level of variation of the shackle centre-to-centre distance to reduce the number of shackles and barrels that will not fit together to less than two per 10,000? Assume all other conditions are as for Part (c) (ii). [20%]

2 A beverages company has developed a novel packaging concept for a canned drink. It utilises a chemical reaction in a closed compartment adjacent to the can to cool the drink before it is poured. They appreciate that there is some considerable risk in delivering such a novel technology to market and aim to utilise good risk management practice during the development of the new product.

(a) List the key requirements for such a canned drink. [20%]

(b) Sketch a fault tree highlighting events that may lead to the customer not enjoying the new beverage experience. [30%]

(c) Sketch a further ‘fault’ tree where the top event represents the successful and profitable launch of the new product and the branches represent events that are required to lead to the top event. [20%]

(d) Discuss the relative merits of using Fault Tree Analysis (FTA) and Failure Mode and Effects Analysis (FMEA) in managing the risk associated with the delivery of new products to market. [30%]

3 A partially completed QFD (House of Quality) chart for a domestic vacuum cleaner is shown in Fig. 2.

(a) Comment on the strengths and weaknesses of using QFD for the design of such a product. [20%]

(b) In Fig. 2, the shaded portion of the Relationships Matrix has not yet been completed. Sketch the 4x4 grid of the shaded portion and fill in the appropriate symbol in each relevant cell. Note that not all cells need be filled in. You may assume that the remainder of the Relationships Matrix is complete. [10%]

(c) What are the priority scores for the first three Engineering Characteristics:

(i) ‘device suction’?
(ii) ‘floor contact pressure’?
(iii) ‘device mass’? [10%]

(d) Overall, which Engineering Characteristic does the QFD chart suggest is the most important? Comment on what factors influence this answer and whether the answer is realistic. [10%]

(e) When considering the correlations between the Engineering Characteristics, which three negative (or strong negative) correlations do you consider to be the most important? Justify your answer. [20%]

(f) Select one of the negative (or strong negative) correlations discussed in (e) and suggest design solutions to this problem. [30%]

(Cont.

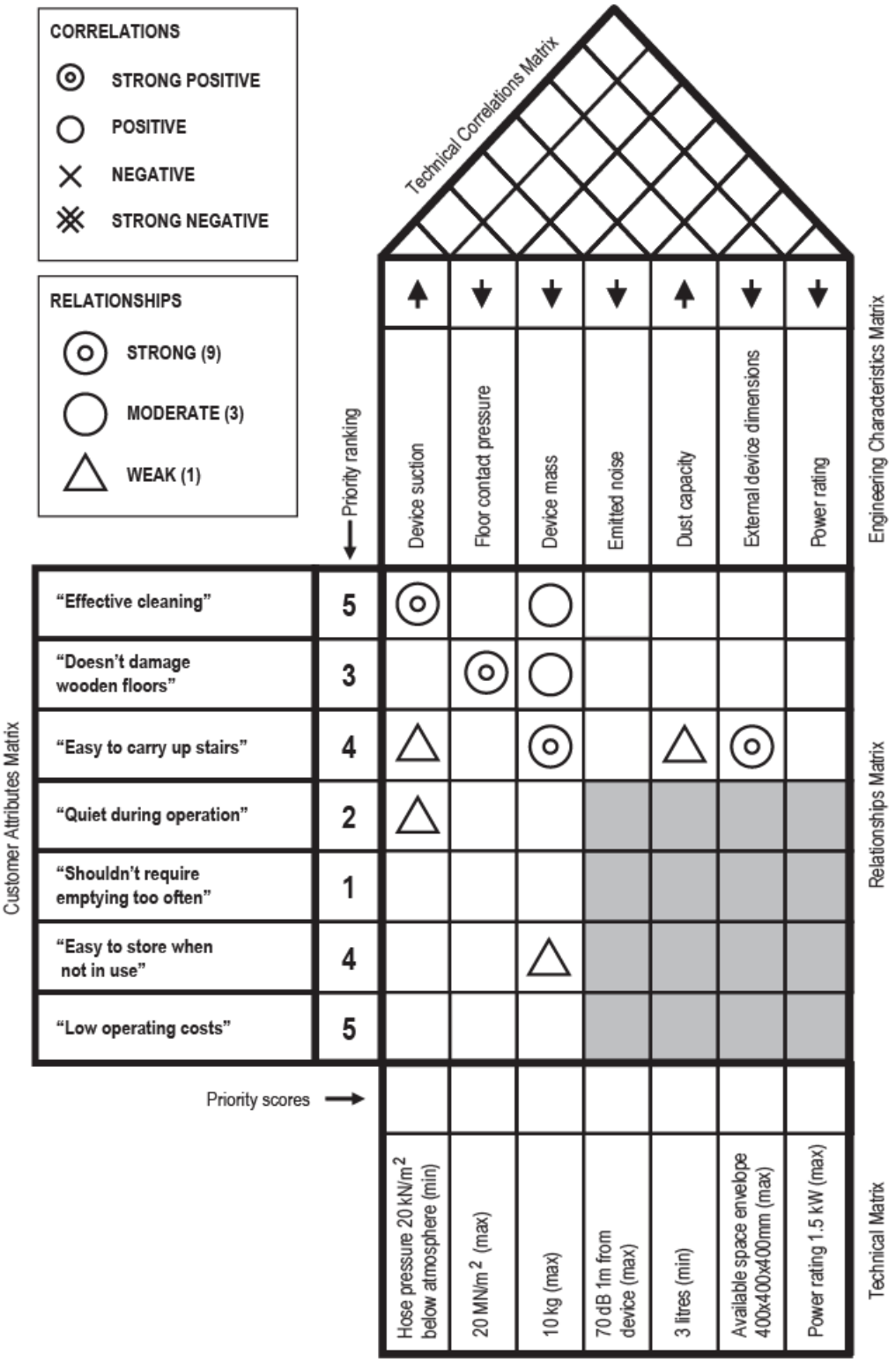
CORRELATIONS
STRONG POSITIVE
POSITIVE
NEGATIVE
STRONG NEGATIVE
RELATIONSHIPS
STRONG (9)
MODERATE (3)
WEAK (1)
Technical Correlations Matrix
Priority ranking
Device suction
Floor contact pressure
Device mass
Emitted noise
Dust capacity
External device dimensions
Power rating
Engineering Characteristics Matrix
Customer Attributes Matrix
"Effective cleaning"
"Doesn't damage wooden floors"
"Easy to carry up stairs"
"Quiet during operation"
"Shouldn't require emptying too often"
"Easy to store when not in use"
"Low operating costs"
5
3
4
2
1
4
5
Relationships Matrix
Priority scores
Hose pressure 20 kN/m2 below atmosphere (min)
20 MN/m2 (max)
10 kg (max)
70 dB 1m from device (max)
3 litres (min)
Available space envelope 400x400x400mm (max)
Power rating 1.5 kW (max)
Technical Matrix

Fig. 2

4 An entrepreneur has identified a market for a small-scale collapsible wind turbine for people exploring the Polar Regions in winter. During transportation, users would carry the wind turbine in a back pack. Once set up, the wind turbine would be capable of charging the batteries of various electrical products (e.g. torches, computers, radios, phones, cameras).

(a) Construct a requirements list for the new wind turbine design. Use several headings to cover the main categories of requirements. Quantify the requirements wherever possible with reasonable order-of-magnitude estimates. [30%]

(b) State the overall function of the wind turbine and list five important sub-functions. [10%]

(c) Construct a combination chart that shows at least two different solution principles for each of the sub-functions you identified in part (b). [20%]

(d) Present two very different designs for the wind turbine. Provide annotated sketches to highlight the features of each design. Comment on the relative strengths and weaknesses of the designs. [40%]

END OF PAPER