MANUFACTURING ENGINEERING TRIPOS PART I

Friday 24 April 2009 9 to 12

Paper P1

DESIGN AND MANUFACTURE

*Answer not more than **four** questions of which not more than **one** may be taken from each section **A, B, C** and **D**.*

*Answers to sections **A, B, C** and **D** must appear in four separate booklets.*

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.*

STATIONERY REQUIREMENTS	SPECIAL REQUIREMENTS
8 page answer booklet x 4	Engineering Data Book
Rough work pad	P1 Data Book
Drawing template x 2	CUED approved calculator allowed
Log - log paper 3 x 2 cycles	

'This paper is accompanied by a separate data book:
P1 Data book 2006 Edition'

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

Version 7

SECTION A

*Answer **one** question from this section.*

1 The components of a bicycle bell are illustrated in Figure 1.

(a) Describe the operating principles of this mechanism. [10%]

(b) Analyse the essential functionality of each component, and name each part to reflect this functionality. Comment on the design-efficiency of this design, and suggest some opportunities for improvement as a result of your analysis. [30%]

(c) Sketch some alternative designs that might improve on this current solution, with annotations to explain your solutions. [30%]

(d) Sketch a fully toleranced engineering drawing for component *A*, making judgements where appropriate on the sizes of the different features, and the material to be used. You should include all of the information necessary to make the part. The component drawing should be completed on the template provided. [30%]

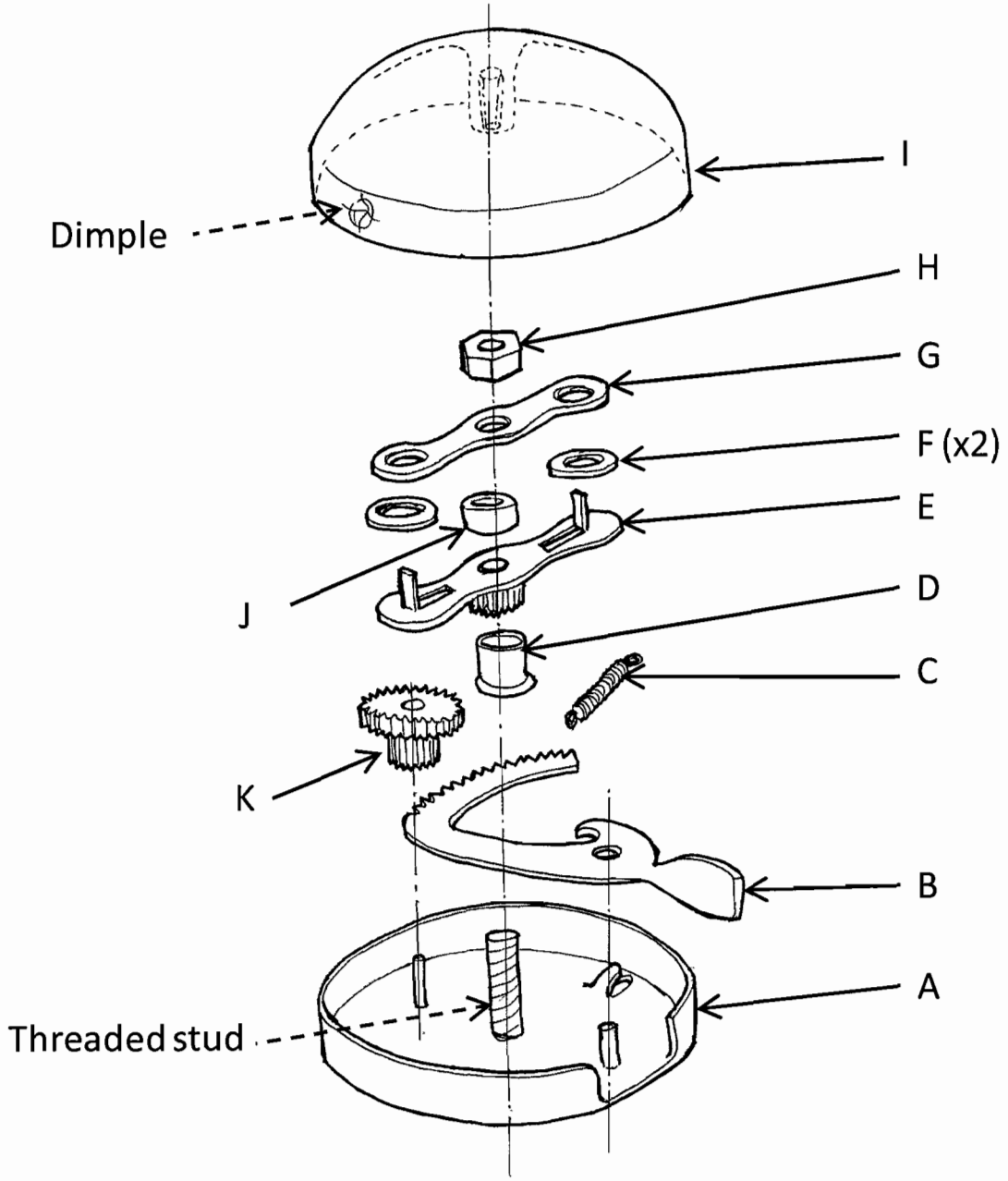

Fig. 1

2 Figure 2 shows a proposed design for a bicycle bottom-bracket unit, comprising a shaft, cylindrical housing, and associated bearings. The two bearings are identical deep-groove ball bearings. The inner diameter of the bearing is 30.0 mm nominal.

(a) Sketch a fully toleranced engineering drawing of the shaft, making assumptions about unknown dimensions as appropriate. The total length of the shaft is approximately 125 mm. You should include all of the information necessary to make the part. The component drawing should be completed on the template provided. Include any necessary geometric tolerances. Any necessary calculations or explanations should be written in the answer booklet. [40%]

(b) Describe the ways in which the manufacturing processes used to produce the shaft might be different for low and high annual production volumes. Comment on the implications for the component cost in both cases. [20%]

(c) Describe how you would calculate the unit cost of the bottom-bracket unit, commenting on the information you would need and the assumptions that you would have to make. [25%]

(d) Discuss ways in which the design of this assembly might be improved. [15%]

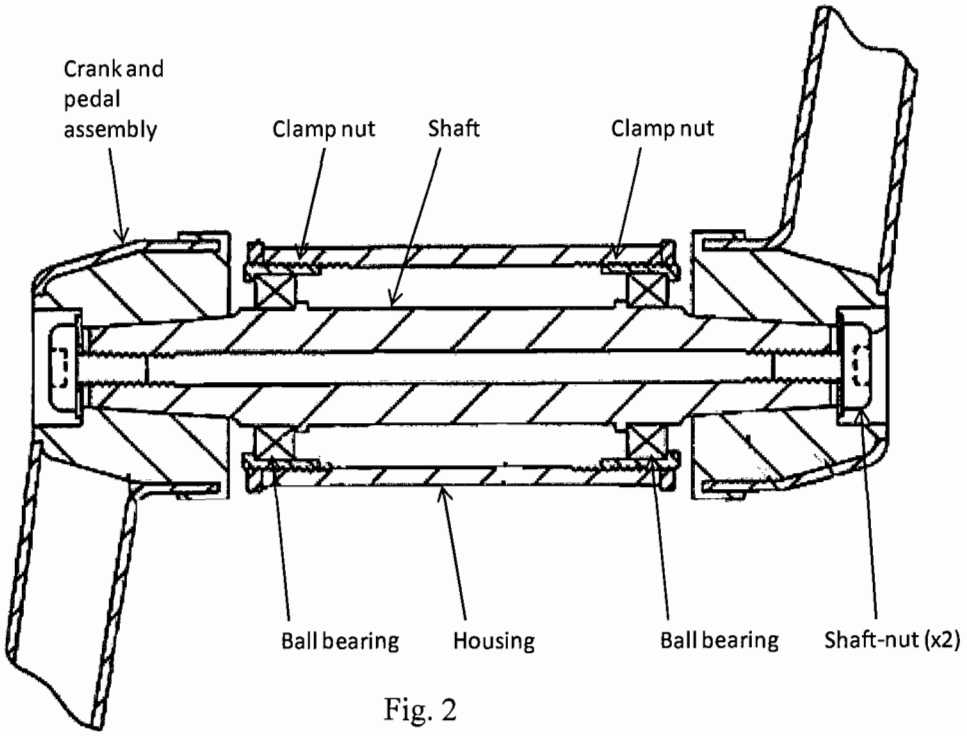

Fig. 2

SECTION B

*Answer **one** question from this section.*

3 (a) Contrast the philosophies of modernism and post-modernism in the design of consumer products. Describe how these principles might be visible in the appearance of products and provide examples to help explain your answer. [20%]

(b) A pen manufacturer makes a range of ball point pens, all based on a standard internal assembly as shown in Figure 3. The outer parts can be varied to appeal to different market segments. Use words and sketches to suggest variations to the visible parts that might appeal to:

(i) an 11 year-old child beginning secondary school; [25%]

(ii) a manager of an engineering firm. [25%]

(c) To further develop your concepts, you might want to assess customer reactions. Suggest two different approaches you might use, indicating the advantages and disadvantages of each. [30%]

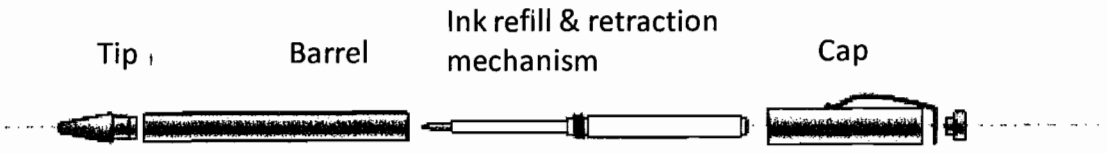

Fig. 3

4 (a) Describe three principles for improving the cognitive usability of a product, providing at least two examples of each principle. [30%]

(b) Figure 4 shows a sketch of a supermarket shopping trolley. Suggest appropriate values for the following dimensions. In each case, comment on the proportion of the population that might be disadvantaged by your choice. The anthropometric data provided in Table 1 may be of use. Explain your reasoning and any assumptions that you make.

(i) Handle height *h1*

(ii) The handle grip diameter *d*

(iii) Handle width *w*

(iv) Basket top, mean height *h2*

(v) Basket bottom, mean height *h3*

[40%]

(c) Apart from the physical attributes of the users, what other factors might be important in deciding the dimensions and form of the trolley? [15%]

(d) With design sketches, suggest possible modifications to the trolley to alleviate difficulties experienced by users when lifting heavy items from the trolley. [15%]

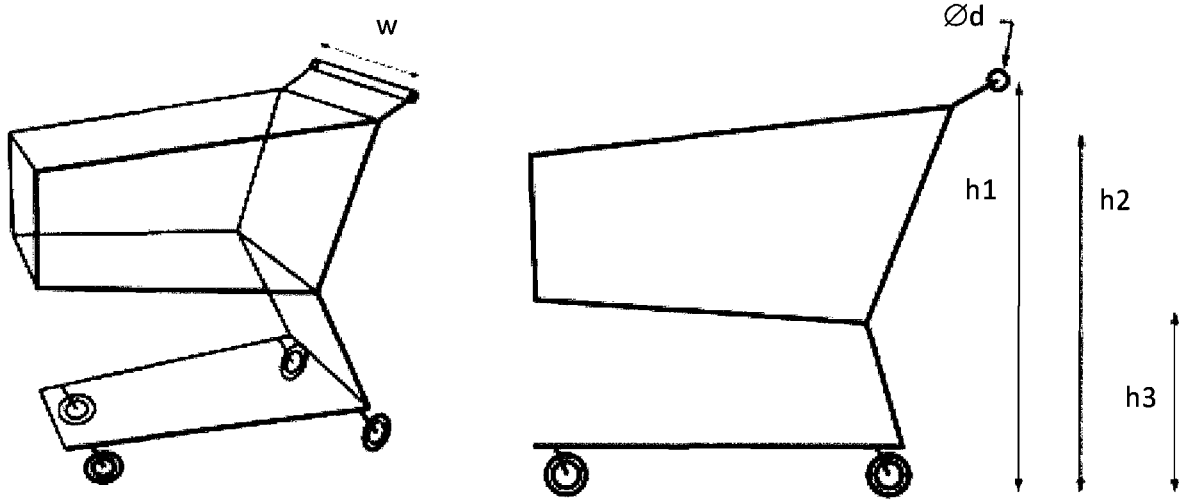

Fig. 4

Measurements in cm	Male			Female		
	5th %ile	50th %ile	95th %ile	5th %ile	50th %ile	95th %ile
Eye height	152.5	163.5	175.0	141.5	151.5	161.5
Elbow height	101.5	110.0	118.5	94.0	101.5	108.5
Hip height	84.5	92.5	100.5	74.5	81.5	88.5
Fingertip height	59.5	66.0	72.0	56.5	62.5	69.0
Knee height	49.5	54.5	60.0	46.0	50.0	54.5
Hip breadth	31.0	35.5	40.5	30.0	36.5	42.5
Arm reach	72.5	78.5	84.0	65.5	71.0	76.0
Shoulder breadth	42.0	46.5	51.0	35.5	39.5	43.5
Comfort grip diameter	4.2	5.2	6.1	3.8	4.3	4.8
Max grip diameter	7.1	7.6	8.1	6.7	7.4	8.1

Table 1

SECTION C

*Answer **one** question from this section.*

5 (a) Describe the main stages of method study, emphasising the critical examination stage of the process. Comment on the limitations of method study. [40%]

(b) A light assembly operation has been redesigned using the principles of method study. Following the redesign, an engineer studies an operator carrying out the assembly operation and records the time taken for every tenth assembly. The results obtained are summarised in Table 2.

(i) Discuss why the assembly times become progressively shorter over the course of the study. [20%]

(ii) Calculate how long it would take to manufacture 1000 assemblies, assuming that improvement continues at the same rate. [15%]

(iii) Calculate how long it would take to manufacture 1000 assemblies, assuming that improvement does not continue beyond 4 hours. [15%]

(iv) By considering the factors that limit improvement, discuss whether the estimate from (ii) is realistic in practice. [10%]

Assembly number	**Time taken (seconds)**
10	189
20	165
30	152
40	143
50	137
60	132
70	128
80	125

Table 2

6 (a) Describe what is meant by line-production. Discuss its advantages and disadvantages compared to other forms of production organisation. Outline the major issues that need to be addressed in designing line-production. [35%]

(b) Describe both qualitatively and quantitatively how activity sampling could be used to determine the cycle times of each station of a six-station assembly line to an accuracy of +/- 10%, with a 95% confidence level. [40%]

(c) Discuss the advantages and disadvantages of using activity sampling rather than other methods to measure cycle times on assembly lines. What method would you choose to produce accurate time standards for a high volume assembly line, and why? [25%]

SECTION D

*Answer **one** question from this section.*

7 (a) Manufactured parts often vary due to changes that occur in the manufacturing process. This variety can be reduced through manufacturing process control.

(i) What are the main causes of variation in the output of a manufacturing process? [10%]

(ii) Discuss, with the aid of the variation equation, the means by which a manufacturing engineer can bring a process under control. [30%]

(b) Chemical etching with hydrogen fluoride (HF) is commonly used to remove silicon dioxide (SiO_2) in semiconductor processing operations. The depth x to which SiO_2 is removed is used as a process output. The depth removed per unit time, dx/dt, is defined as the etching rate, r, and depends on the concentration of HF, C_{HF}, and on absolute temperature, T, according to:

$$r = kC_{HF} \exp(AT)$$

where k and A are constants for the process.

(i) If the process removes material only in the depth direction, determine the variation equation. Your answer should include expressions for the sensitivity quotients relating to HF concentration, temperature, and time. [30%]

(ii) Determine the variation in the depth of etch for a variation in etching time Δt = 4 seconds, for etching at a temperature of 300 K and an HF concentration of 0.02 mol litre^{-1}. Assume that k = 0.005 nm litre mol^{-1} s^{-1} and A = 0.05 K^{-1}. [30%]

8 (a) Condition monitoring is applied across a range of manufacturing industries in order gain information about the performance of the manufacturing process. Briefly describe six methods by which you could monitor the condition of a cutting tool in a machining centre. [20%]

(b) You are responsible for two manufacturing lines that deliver precision Al_2O_3 ceramic washers for a new type of tap fitting. Both lines operate under the same standard operating conditions. The Upper Specification Limit of the line for the thickness of the washers is 3.52 mm and the Lower Specification Limit is 3.18 mm. Line 1 produces washers with a mean thickness of 3.35 mm and a standard deviation of 0.07 mm. Line 2 produces washers with a mean thickness of 3.43 mm and a standard deviation of 0.05 mm.

(i) Briefly describe a means by which you could manufacture such a washer. [20%]

(ii) Calculate the C_p and C_{pk} values for each line. [20%]

(iii) Calculate the percentage of parts that are within the specification limits for each line. [20%]

(iv) Discuss the implications of your results to parts (ii) and (iii), and describe how the production process might be improved. [20%]

END OF PAPER