MANUFACTURING ENGINEERING TRIPOS PART I

Friday 25 April 2008 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.*

There are no attachments.

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

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 You are a junior design engineer in a company that makes precision instruments. Your chief engineer has sketched a simple indexing mechanism, shown in Figure 1. The mechanism should use the motor shown in Figure 2. The motor rotates continuously; component 2 rotates in 90 degree steps.

(a) Using annotated design sketches, design a means of holding this complete assembly. You may make modifications to components 1 and 2 as appropriate to optimise your design. Explain how you arrived at your solution and specifically comment on the implications of your design for the relationships and dimensions of the components. [50%]

(b) Making appropriate judgements on the dimensions and tolerances of components, sketch a manufacturing drawing for each of components 1 and 2 (as used in your design). You should include all of the information necessary to make these parts. Component drawings should be completed on the templates provided. [50%]

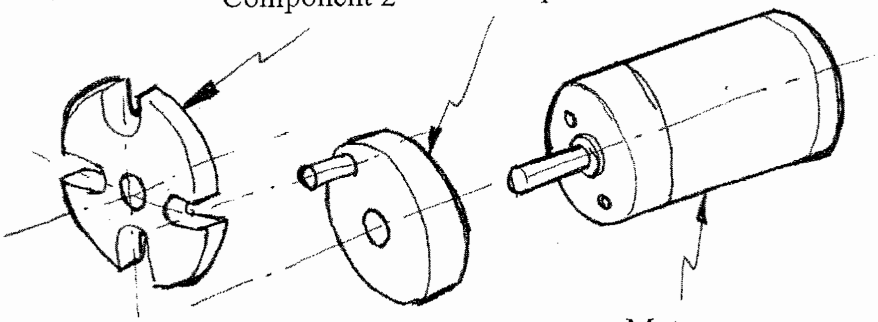
Component 2
Component 1
Motor

Fig. 1

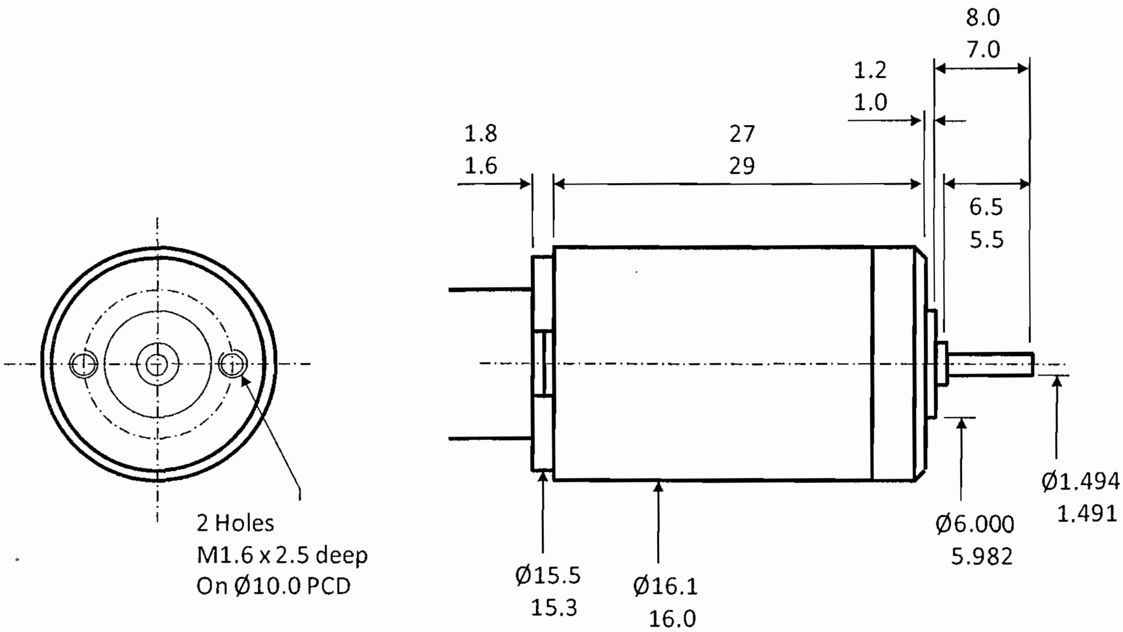
8.0
7.0
1.2
1.0
1.8
1.6
27
29
6.5
5.5
2 Holes
M1.6 x 2.5 deep
On Ø10.0 PCD
Ø15.5
15.3
Ø16.1
16.0
Ø6.000
5.982
Ø1.494
1.491

Fig. 2

2 (a) What is the relationship between unit cost, price and value of a successful product? Why is this of relevance to the design team? Illustrate your answer with examples where appropriate. [15%]

(b) What are the factors that you would need to consider when estimating the cost of a new machined component and how might cost be minimised? [20%]

(c) A small bore has been specified with a diameter of 6.0H6. Six batches, each consisting of ten components have been produced; three batches by Steve and three by Terry. The batches have been inspected, with the results shown in Table 1. Using graphs and calculations where appropriate, discuss the implications of these results and the steps that you would recommend to improve production. [60%]

	Steve			Terry		
	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6
Standard deviation	0.0012	0.0013	0.0015	0.0005	0.0002	0.0005
Mean	6.003	6.004	6.004	6.005	6.002	6.006

Table 1

(d) A precision component has a flat datum surface, with a specified surface finish of 0.8 μm Ra. Which production process would you recommend and why? [5%]

SECTION B

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

3 (a) An over-centre wedge consists of two equal length rods, which hinge together so that they act like a leg, lengthening as the knee straightens and then becoming rigid as the knee goes slightly over centre and locks. Such a wedge is able to provide a very high axial force F for a small closing forces applied laterally at the knee. The lengths of the rods can be finely adjusted so that the knee of the wedge mechanism is a lateral distance x away from the straight position when the two ends of the wedge contact the two reaction faces. The rods are of length L, cross sectional area A and are made with a material of Young's Modulus E. The mechanism is illustrated in Figure 3.

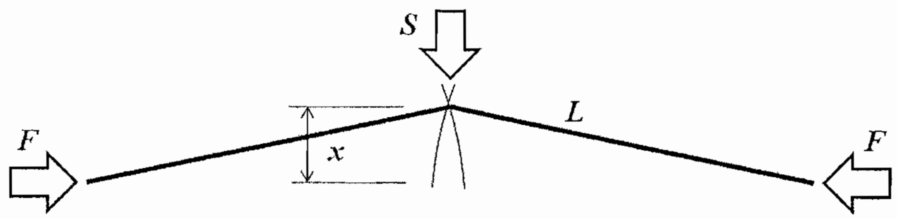

Fig. 3

(i) Derive an equation expressing the axial wedge force F when the mechanism becomes straight, in terms of x and L. [10%]

(ii) Derive an equation expressing the axial force F in an intermediate position with lateral displacement y. [10%]

(iii) Derive an equation expressing the sideways force S required to close and open the wedge, in terms of y, x and L. [15%]

(iv) Establish the maximum value of S in terms of F, x and L. [15%]

(b) What are the necessary degrees of freedom and constraint, and ranges of degrees of freedom, required in this adjustable wedging mechanism? [20%]

(c) A handed end detail on the rod where the rods meet allows two identical rods to be used to make the wedge. Sketch a possible embodiment which will achieve the desired functionality and explain your sketch. [30%]

4 (a) Any natural material displays a variation in structural properties. These variations can be brought under control, partly by selection and partly by treatment processes. In simple language, explain how you would organise a series of experiments to efficiently explore the effects of variations in key parameters. Describe how you would begin these experiments, how you might refine the results and in what way the experiments are efficient. [40%]

(b) Components are to be made of strips of bamboo. Four factors that influence the stiffness of these bamboo strips have been identified and are summarised in Table 2. Representative samples have been taken and the average stiffness values in relation to these factors are summarised in Table 3.

(i) Calculate the effects of the variations in each factor and indicate the maximum stiffness that could be achieved, explaining the results. [30%]

(ii) Discuss how you could optimise both the stiffness of the samples and the utilisation of the bamboo material, explaining your reasoning and providing calculations where appropriate. [30%]

Factor	Level 1	Level 2	Level 3
Moisture content %	3	6	9
Thickness mm	1	1.5	2
Location on stem	Lower	Middle	upper
Age (years)	3	4	5

Table 2

Experiment Number	Moisture Content	Thickness	Location	Age	Stiffness GPa
1	1	1	1	1	30.00
2	1	2	2	2	31.25
3	1	3	3	3	28.75
4	2	1	2	3	29.40
5	2	2	3	1	26.90
6	2	3	1	2	24.40
7	3	1	3	2	26.90
8	3	2	1	3	24.40
9	3	3	2	1	23.75

Table 3

SECTION C

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

5 (a) Define 'time study' and describe in detail how this method is used to set accurate time standards for manual manufacturing operations. Explain the significance of the 'standard time' of an operation. [40%]

(b) An industrial engineer studies a light manual assembly operation, which has recently been introduced into a factory. After 197 assemblies have been completed, he observes 5 repetitions of the operation, with the following results:

118.0 s; 129.0 s; 126.0 s; 111.0 s; 117.0 s.

He also carries out an MTM-1 analysis and arrives at a time of 3500 TMU. At the same time the following day, when a total of 397 assemblies have been completed by the same operator, he repeats the observations, with the following results:

104.0 s; 107.0 s; 103.8 s; 104.4 s; 105.8 s.

(i) Calculate the 95% confidence limits for the observed times. [20%]

(ii) Comment on any differences among the observed times and the MTM analysis. [5%]

(iii) If the total order quantity of the assemblies is 1000, estimate the total time that will be taken in assembly. You can assume that the factory works a 35 hour week, over 5 equal days. Explain your reasoning and any further assumptions that you make. [35%]

6 (a) You have been asked to plan in detail the layout of a new factory. Describe the stages that you would go through, the factors that you would take into account at each stage and the analytical tools and techniques that you would use. [60%]

(b) Briefly describe the differences between a cellular production layout and a process (functional) layout. For a company that manufactures a wide range of products, discuss the benefits of group technology and cellular layout compared to a functional layout. [40%]

SECTION D

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

7 (a) Jigs and fixtures are important elements of a manufacturing system and are used in a wide range of manufacturing operations.

(i) What is the principle of Isostatism? [10%]

(ii) Describe the main design requirements of jigs and fixtures and detail their functional elements. [40%]

(b) An item to be machined is shown in Figure 4. Sketch the design of a jig that will enable the large hole to be machined and identify the degrees of freedom the jig is controlling. [30%]

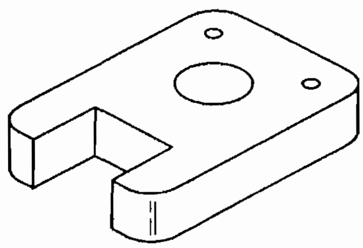

Fig. 4

(c) Figure 5 shows the location of the hole and its tolerances. What is the jig tolerance in this case? [20%]

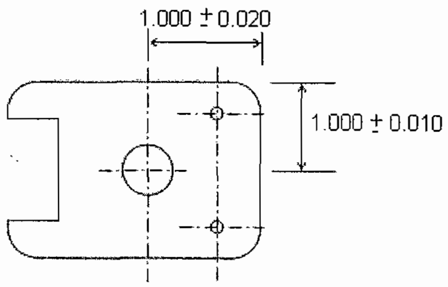

Fig. 5

8 The F-22 fighter-jet cockpit canopy is the largest piece of polycarbonate formed in the world with the largest Zone 1 (highest quality) optics for compatibility with helmet-mounted head-up display systems. The F-22's canopy is 3.5 m long, 1.2 m wide, 0.7 m tall, and weighs 180 kg. A schematic of the canopy is shown in Figure 6. The design constraints are as follows:

- It must be made in one piece of transparent polycarbonate and have a uniform thickness of 20 mm +/- 0.1 mm.
- It must have an optical finish such that the surface roughness does not exceed an Rz value of 25 nm.
- It must be coated with an external anti-reflection oxide layer to defend the pilot against enemy lasers.
- It must be coated with an internal reflective oxide layer to enhance the head-up display image.

Fig. 6

(a) Your company has been asked to develop a manufacturing route for the cockpit canopy with production volumes of 10 per week. Detail the manufacturing steps for this component, paying particular attention to the design, inspection and operation of any tooling that is required. Use sketches to support your answer. [60%]

(b) In order to manufacture to specification it is necessary to implement a number of in-process measurements, without damaging the component. Measurements include surface roughness, surface form, and thickness of the oxide coatings. Briefly describe the measurement techniques that could be employed to obtain this information. [30%]

(c) Initial trials with a prototype unit have determined that the service life is limited to 9 months due to gradual failure of the optical coatings. Suggest a further manufacturing step that may increase the service life. [10%]

END OF PAPER