MANUFACTURING ENGINEERING TRIPOS PART I

Saturday 24 April 2004 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.*

Attachments:
Log-log paper (1 sheet)

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

SECTION A

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

1 (a) When redesigning a mechanism, what are the four key questions to consider in order to map its functionality? [25%]

(b) The pedal harp as shown in Fig.1 was developed as a musical instrument in the early 1800s. It has 47 strings, each of a particular length, weight and tension. At the base of the harp are seven pedals corresponding to the seven notes A - G in an octave, each pedal held up by a spring. When for instance the 'A' pedal is pushed down one notch by the musician's foot, the pedal operates a linkage which goes up inside the pillar of the harp and then across inside the neck of the harp through a series of short links, to turn each disk in the first row of disks which is behind an 'A' string. Each of these disks carries a pair of pins which trap the string between them and shorten its effective length, thus raising the note from 'A' flat to 'A' natural. Figure 1 shows a simplified illustration of this first set of linkages for one of the seven pedals.

This mechanism has a very large number of components in it and the design has remained essentially the same for over 150 years. You have been asked to simplify it.

(i) List the sequence of components in the linkage shown in Fig.1 and describe the function that each component fulfils. [15%]

(ii) Apply the four key questions to the mechanism as a whole and describe the essential functions that will have to be fulfilled by such a mechanism. Indicate which components you probably need to keep and why you need to keep them, and indicate which components might be replaced by something else. [30%]

(iii) Propose a simpler way of fulfilling the function provided by the existing mechanism. Sketch your proposed mechanism, describing the individual components and explaining how they provide the functionality that is required. [30%]

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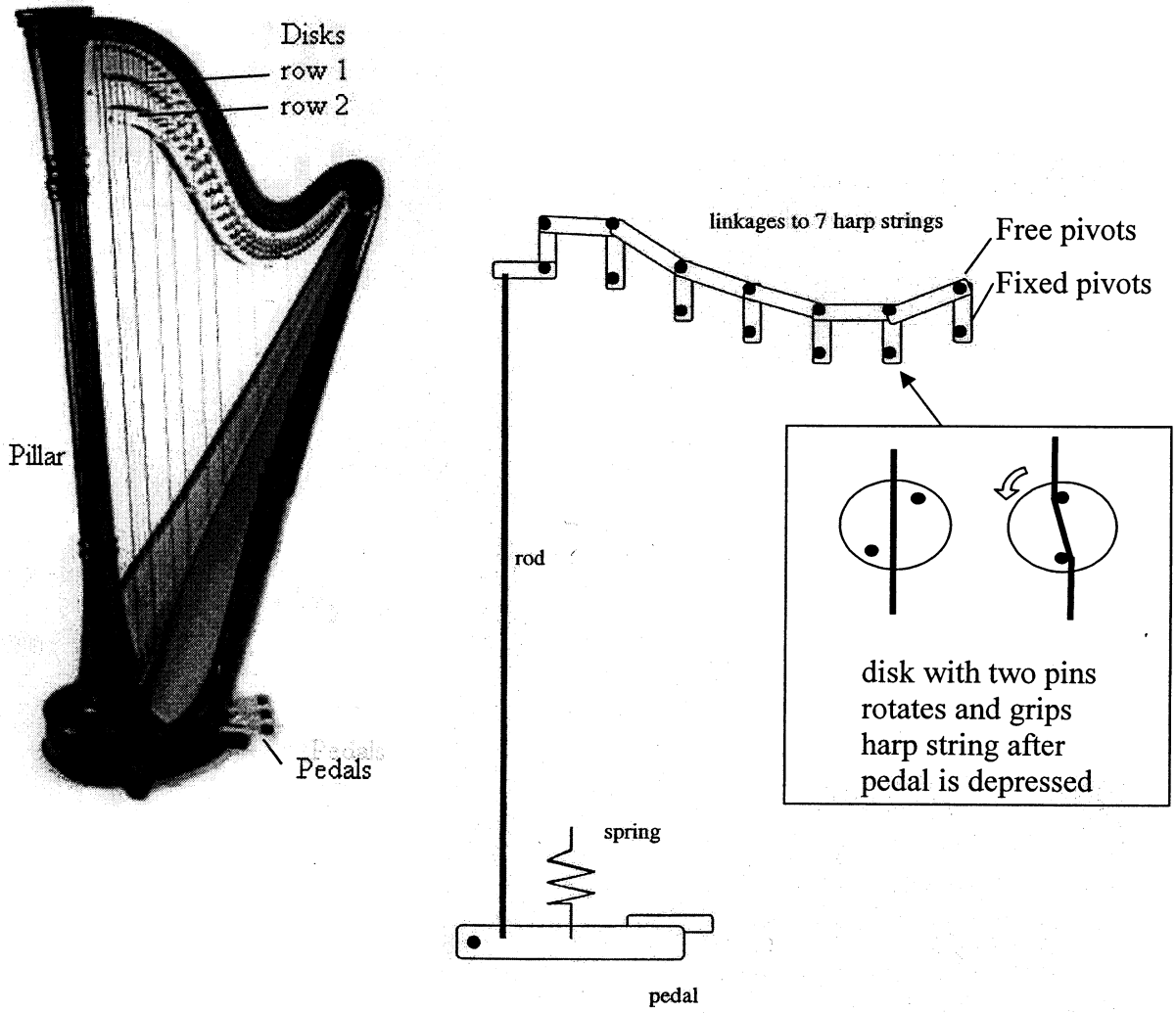
Disks
row 1
row 2
Pillar
Pedals
linkages to 7 harp strings
Free pivots
Fixed pivots
rod
disk with two pins
rotates and grips
harp string after
pedal is depressed
spring
pedal

Fig. 1

2 A two-stroke engine has four timing parameters to do with its breathing, that interact with each other. A set of nine experimental engines have been made, involving different combinations of settings for the four parameters. Each parameter can have one of three settings as indicated in Table 1. The values of the timing parameter settings are expressed as degrees past top dead centre as the crankshaft revolves. The parameter settings used in the nine engines are shown in Table 2. Table 2 also shows speed (rpm) achieved by each engine with the same load. A higher speed indicates higher power output.

Parameter	**Timing Parameter Settings**		
	1	**2**	**3**
Inlet Open (I.O.)	195	210	225
Inlet Close (I.C.)	0	15	30
Transfer (T.)	150	155	160
Exhaust (E.)	135	140	145

Table 1

Engine	**Timing Parameter settings**				**speed**
	I.O.	**L.C.**	**T.**	**E.**	**rpm**
1	1	1	1	1	20,200
2	1	2	2	2	21,200
3	1	3	3	3	20,300
4	2	1	2	3	20,700
5	2	2	3	1	21,500
6	2	3	1	2	20,400
7	3	1	3	2	21,700
8	3	2	1	3	21,300
9	3	3	2	1	20,800

Table 2

(cont.

(a) Explain why this number of experiments is adequate to understand the combined effects of these four parameters. Explain the method you would use to establish the effect of different settings for each of the four parameters and calculate the results that come from this set of tests. Estimate the likely speed for the best possible combination of parameter settings. [50%]

(b) Propose new values for timing parameter settings for a second set of tests to optimise the performance further, explaining your reasoning. [35%]

(c) Show how the analysis of variance method used in the example above is analogous to the Fourier analysis of a signal. [15%]

SECTION B

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

3 You have been asked to design a small Refrigerator.

(a) (i) Describe the elements of the 'design mix' which must be considered during the design of this product. [20%]

(ii) Outline the role of Quality Function Deployment in the design process for the refrigerator and discuss the strengths and weaknesses of this tool. [20%]

(iii) Figure 2 shows a sketched section through the refrigerator (lower portion only). There have been some difficulties in manufacturing, with interference between the Shelf (4) and the Door Tray (1) at 'A'. Suggest changes to the design to eliminate this difficulty, supporting your answer with calculations and sketches. [20%]

(b) Describe the potential sources of inaccuracy in the manufacture of a machined component and outline two alternative strategies to ensure dimensional accuracy in production. [20%]

(c) Describe the working principle behind a 'go/no-go' plug gauge. Specify the dimensions of the 'go' and 'no-go' ends of a plug gauge which could be used to inspect a 12 mm diameter hole with an H6 tolerance applied. [20%]

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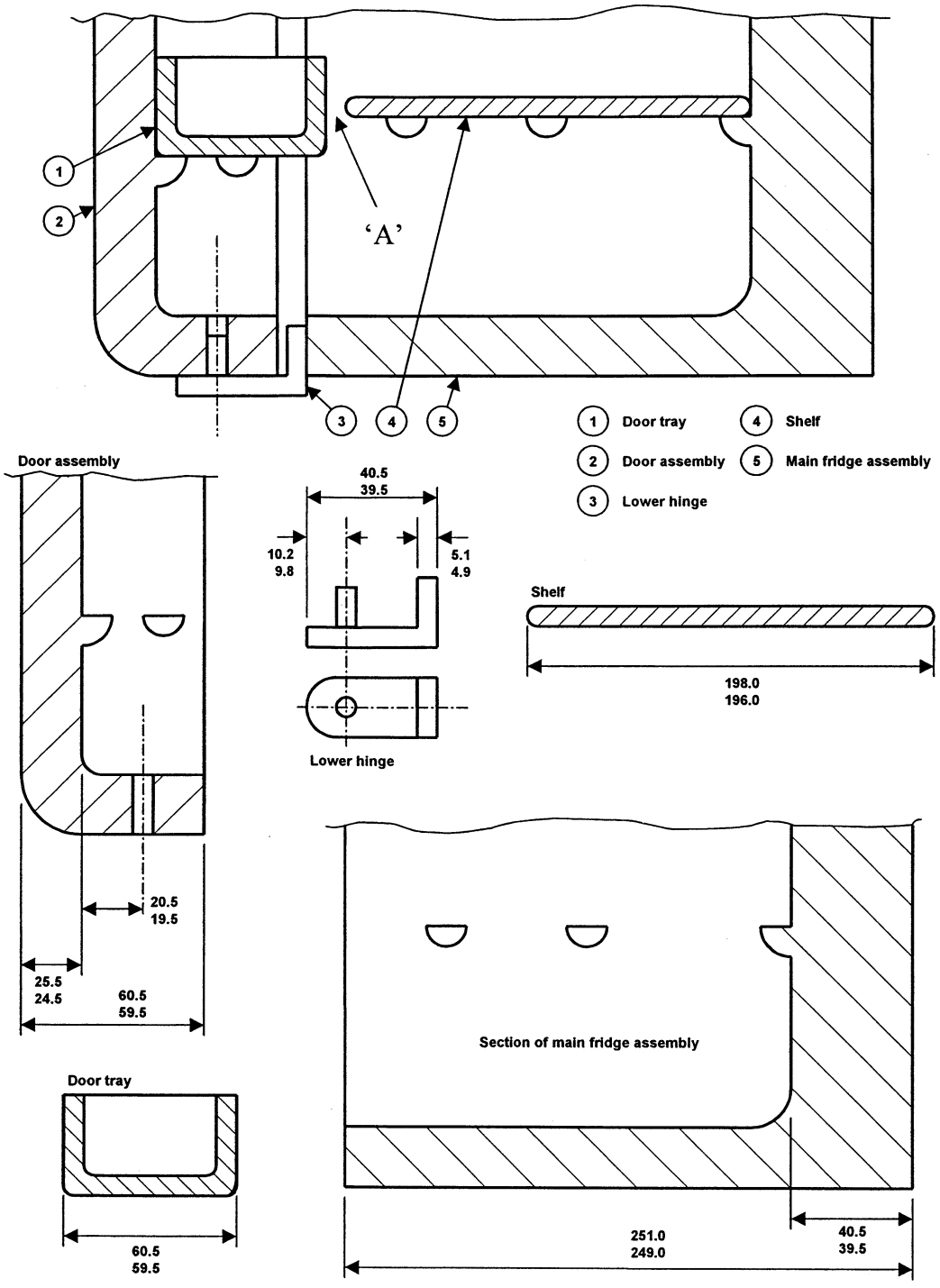

1
2
'A'
3
4
5
1 Door tray
2 Door assembly
3 Lower hinge
4 Shelf
5 Main fridge assembly
Door assembly
40.5
39.5
10.2
9.8
5.1
4.9
Lower hinge
Shelf
198.0
196.0
20.5
19.5
25.5
24.5
60.5
59.5
Door tray
60.5
59.5
Section of main fridge assembly
251.0
249.0
40.5
39.5

Fig. 2

4 You are responsible for the design of a new machine tool for the manufacture of small, precise components.

(a) Describe how you would segment the marketplace for this product and how this might assist you in collecting user needs. [25%]

(b) The machine tool includes a precision air spindle. The spindle shaft rotates relative to the housing at high speed, and has a nominal outside diameter of 30 mm with a g6 tolerance applied. The first batch of components for the shaft has been produced and a sample of 100 parts has been inspected. As measured across the sample, the average diameter is 29.9900 mm and the standard deviation is 0.0007 mm. With calculations and diagrams where appropriate, what are your recommendations to the machinist and the designer? [35%]

(c) With the aid of sketches, describe the possible form errors in the manufacture of such a cylindrical feature. [10%]

(d) Figure 3 shows a sketch of the spindle with a geometric tolerance to control cylindricity. How else could the geometry of this feature be controlled? Use appropriate sketches to illustrate your answer where appropriate. [20%]

(e) The designer has failed to specify a surface finish requirement for this feature. What would your recommendation be and what implications does this have for the finishing process used? [10%]

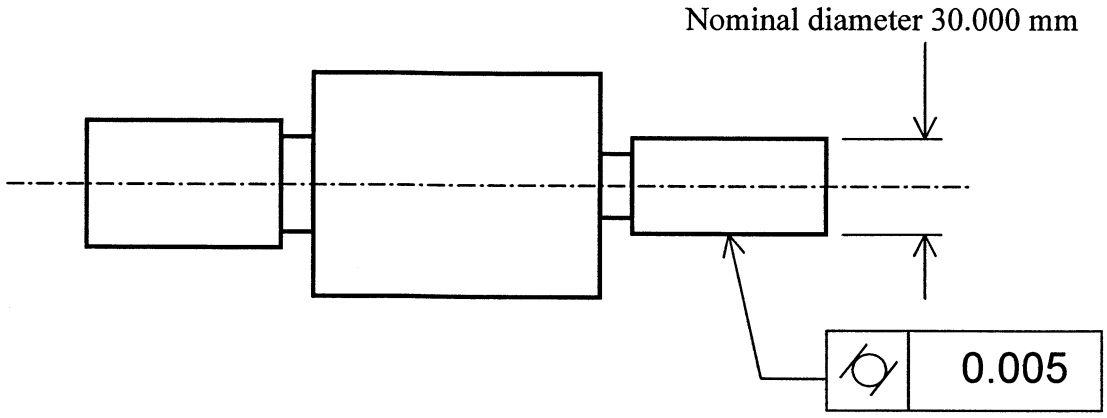


Fig. 3

SECTION C

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

5 A company manufacturing a range of components for the automotive aftermarket has reorganised its manufacturing system by employing ideas from 'Group Technology' and changed from a functional to cellular layout.

The cellular layout became operational in January 2003. The company monitored the average production cost of a family of components over the period January to June 2003, with the results shown in the Table 3 below.

In order to prepare a budget, the company required an estimate of the average cost per thousand products over the period July 2003 to June 2004.

(a) Briefly discuss the concept of 'Group Technology', and describe the difference between a functional and a cellular layout. [20%]

(b) Discuss the reasons why moving to 'Group Technology' and cellular layout might reduce the production cost. [30%]

(c) Make two estimates, a lower bound and an upper bound, for the average cost per thousand products for the financial year July 2003 to June 2004, clearly stating the assumptions that you make for each estimate. [40%]

(d) Which estimate do you think is the more realistic? Discuss your reasons. [10%]

Month	**Cost/1000 products (£)**
Jan 2003	13,000
Feb 2003	11,700
Mar 2003	11,000
Apr 2003	10,530
May 2003	10,180
Jun 2003	9,900

Table 3

6 (a) Define 'Method Study', and briefly describe its main stages. [20%]

(b) You have been asked to study the utilisation of an overhead crane serving a heavy machine shop, and have decided that 'activity sampling' is the technique that you will use. A preliminary estimate of the utilisation is 80%. Describe in detail how you will carry out the study. Your description should specify the number of observations to take, and relate these to the accuracy of the study. [60%]

(c) Instead of 'activity sampling' you could have used 'time study' to measure the utilisation. Outline the advantages and disadvantages of using 'activity sampling' rather than 'time study' for this case. [20%]

SECTION D

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

7 (a) Describe the four basic principles of surface creation and for each one identify the main features of the medium of transfer. [15%]

(b) BMW are about to commence production of a limited edition sports car with an estimated production volume of fifty thousand units over several years. You have been asked to provide the single shot injection mould tools for the rear light clusters.

(i) Describe the manufacturing process route for the tooling. Your answer should include a discussion of the materials options giving reasons for your choice, the various means of cavity production including finishing requirements and the economic considerations that may influence your decision making. [50%]

(ii) The BMW light cluster has a maximum projected area of x cm^2 and a depth of y cm. The designers wish to maintain the projected area and increase the depth of the moulding to $2y$ cm, whilst keeping the wall thickness constant. What effect do these changes have on the selection of the process parameters for the injection sequence? What effect would increasing the number of cavities from one to three have on the process parameters for the injection sequence? [15%]

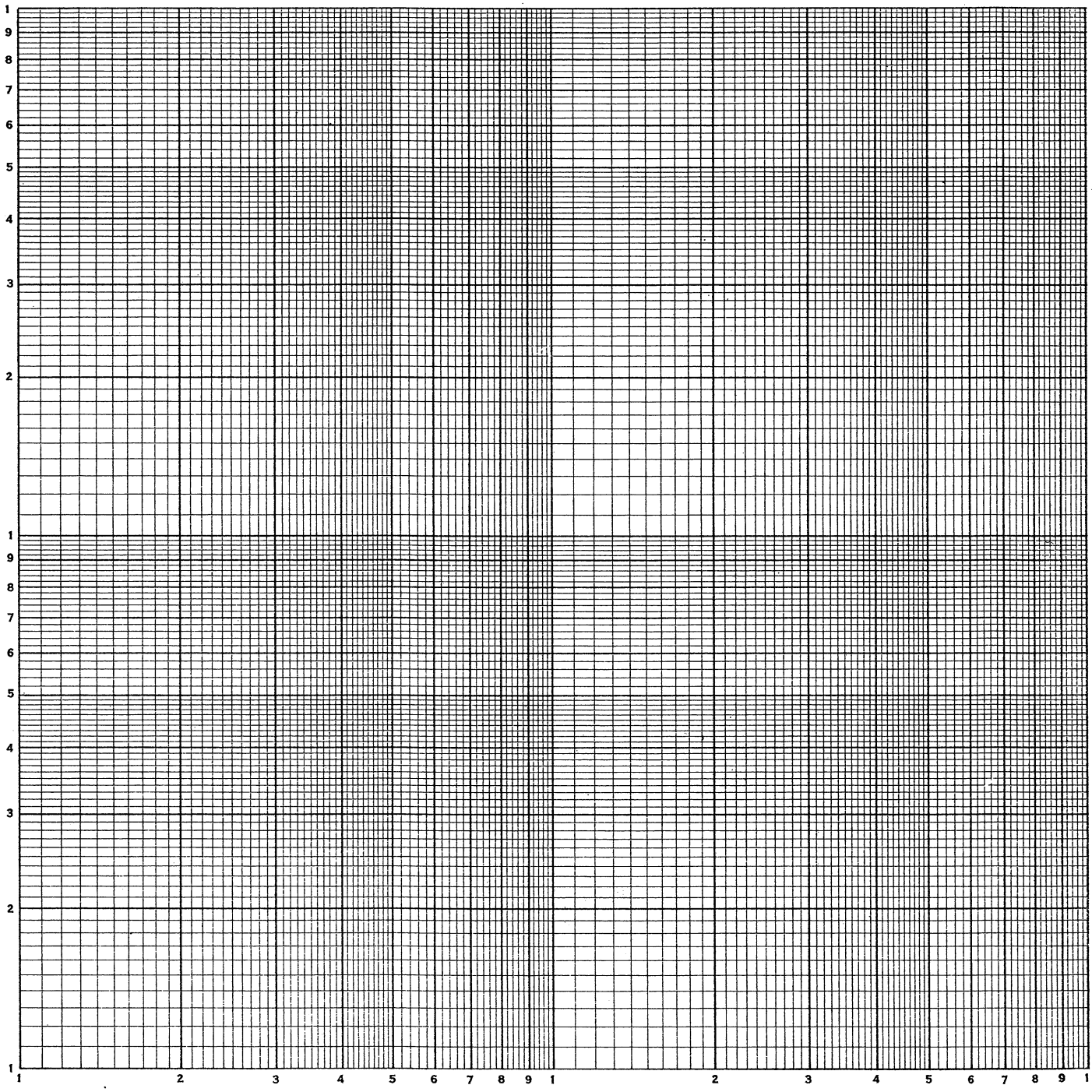
(c) Dimensional deviations in the production of an injection mould considerably affect the precision of the plastic mouldings from the mould. A dimensionally accurate mould is the most important condition for the mass production of high quality mouldings. However, the dimensions of a moulding are always smaller than those of the mould cavity. For a typical injection moulding operation, sketch a graph of moulding dimension against time. Your sketch should begin with the start of the injection sequence and end 24 hours later. Identify the causes of dimensional change against time. [20%]

8 (a) A production process may involve a change in the properties of an object including geometry, hardness, state, shape etc. To produce any change in property three essential agents must be available. Describe these agents and provide a general morphological process model that can be used to describe any manufacturing process. [25%]

(b) What are the three main categories of basic processes? Give three examples for each category. [20%]

(c) Discuss in detail the three types of material flow that maybe involved in changing the shape of an object. In each case support your answer with a description of the relevant manufacturing process. Identify possible sources of process variability for each production process and suggest ways in which these can be minimised. [55%]

END OF PAPER



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