MANUFACTURING ENGINEERING TRIPOS PART II

Wednesday 26 April 2006 9 to 12

PAPER 1

Answer not more than ***four*** *questions. Answer* ***each*** *question in a separate script paper booklet.*

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
8 Page Script Paper Booklet x 4
Rough Work Pad

SPECIAL REQUIREMENTS
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) In the context of the process for making an integrated circuit (IC), explain what is meant by the terms:

(i) epitaxy;
(ii) photolithography;
(iii) diffusion and implant. [30%]

(b) Table 1 below shows typical yield values for various key stages of the IC manufacturing process.

Process stage	**Yield**
Wafer processing	94%
Wafer probe	50%
Assembly	96%
Final test	90%

Table 1: Typical yield values

Explain what is meant by each of these stages, and discuss the factors affecting the yield value at each stage.

Calculate the overall yield for the IC manufacturing process. [50%]

(c) Describe the different types of integrated circuits that are currently manufactured (i.e. the purposes to which they are applied). In what way might you expect their different characteristics to affect the yield values above. [20%]

2 (a) Describe the following two 'rapid prototyping' processes:

(i) stereolithography;
(ii) selective laser sintering.

For each process, indicate any restrictions on the materials for which they can be used.

Discuss the opportunities for the use of these, and other similar additive manufacturing processes, in the manufacture of products, rather than just in prototyping. [40%]

(b) Describe the following three processes for surface engineering:

(i) anodizing;
(ii) high-velocity oxy-fuel spraying;
(iii) PVD coating.

For each process, indicate any limitations in the substrate material which can be treated, and in the composition of the resulting surface. [30%]

(c) A manufacturer of garden implements proposes to market spades, made from a stainless steel, with a surface treatment. The aim of the treatment is to reduce the work of digging by lowering the friction against the soil, and also to reduce wear of the spade. Discuss which, if any, of the processes listed in part (b) above might be suitable for this application. Explain how you would plan a development project to evaluate potential surface treatment methods and materials. [30%]

(TURN OVER

3 (a) Explain what is meant by 'sustainable manufacturing', and list four approaches which can be used to achieve a more sustainable manufacturing process. How does sustainable manufacturing differ from 'lean manufacturing'? Discuss the similarities and differences between these two paradigms. [30%]

(b) Discuss how improved sustainability can be achieved in the automotive industry.

(i) In what ways do the approaches you propose reduce environmental impact?

(ii) To what extent are the approaches you propose already being used?

(iii) How might changes in patterns of vehicle ownership (e.g. leasing from manufacturers rather than purchase) alter the environmental impact of this industry? [35%]

(c) Outline the process used to fabricate aerospace components from Carbon Fibre Reinforced Plastic (CFRP). Discuss the sources of waste, and the methods which can be used to reduce waste, at each stage of the process. Compare and contrast the opportunities for recycling CFRP at end-of-use with those for recycling polymers used in packaging for domestic consumer products. [35%]

4 Process Intensification (PI) describes a strategy for the next generation of process plant operations.

(a) Describe what is meant by PI. [20%]

(b) Provide a detailed discussion of:

(i) the benefits of PI; [25%]

(ii) the problems that companies encounter when implementing this process strategy. [25%]

(c) The fundamental law of heat conduction across an interfacial medium of thickness x and cross sectional area A may be written as:

$$\dot{Q} = \frac{\partial Q}{\partial t} = -KA\frac{\partial \theta}{\partial x}$$

where Q is the heat that flows perpendicular to the interface, K is the thermal conductivity of the medium, θ is the temperature, and t is time.

Use this expression to describe how the rate of heat flow can be intensified in a process operation and suggest which plant components may benefit from the technique. [30%]

5 A large modern bakery contains an automated bread production line with a capacity of 1 million loaves per week. Mixed dough is dispensed into tins which move on a continuous conveyor through proving, baking and cooling stages. Product is then separated from the tins and passed to several parallel lines where bread is sliced, wrapped and packed. The tins return to the beginning of the process.

There are six basic products made in batches which vary from 2 to 12 hours duration. Variety increases by a factor of about 10 through pack variations. There is no size variance on the bread line. Batch changeovers involve about 5 minutes' loss of production.

There are 13 x 12 hour production shifts per week and one (Saturday) 12 hour maintenance shift. 40 shift production workers are employed on bread manufacture and packing. Sickness absence averages 5.5% and staff turnover is 12% per year. Overtime is over 10%.

The plant meets all regulatory requirements for the food industry but is rather untidy with waste and surplus packing materials littering the packing and dispatch area and tools and other maintenance equipment around the production line. The large engineering workshop is cluttered with work in progress, but there is no evidence of maintenance job planning.

(a) You are requested to assess the performance of this plant from a manufacturing point of view. List and define two measures for each of the following categories:

- (i) customer service;
- (ii) internal efficiency;
- (iii) system performance.

How might you use benchmarking in this assessment and what types of plants could you use for comparison? [30%]

(cont.

(b) In order to estimate the potential for greater throughput, you collect the data given in Table 2.

Parameter	Bread Line
Conveyor speed	Averages 97% of design.
Waste	1% of bread material waste and 0.5% of packing material is wasted at changeovers. A further 2% of material is lost due to minor problems and intentional overruns. Material balances reveal a further 1.5% unaccounted waste.
Routine maintenance	1 x 12 hour shift per week.
Scheduled outages average per 12 hour production shift	Cleaning 40 minutes. Changeovers 20 minutes.
Unplanned stoppages average per 12 hour shift	30 minutes for jams, short breakdowns, adjustments, etc.

Table 2: Data on bread line

Estimate for the bread line:

(i) product rate efficiency, quality rate efficiency, and availability;
(ii) overall equipment effectiveness (OEE).

What value of OEE would you set as an improvement target for the bread line and why? What % increase in weekly throughput on the bread line could be achieved if this target were met? [40%]

(c) Although management are seeking to increase throughput, operating staff are suspicious and likely to be uncooperative. Operating staff believe too much is already expected from them with a tiring shift system and imposed overtime.

(i) Bearing in mind the anxieties of the workforce, what are the first activities you would recommend to increase bread line throughput?

(ii) What steps should then be followed in a programme of improvement? [30%]

(TURN OVER

6 (a) Discuss, in detail, the advances in machine tool technology which have enabled the rapid economical manufacture of customised components in small batches. [60%]

(b) Identify the problems that might arise in integrating an advanced CNC machine tool with a robot performing the part loading, unloading and ancillary operations (e.g. deburring). Discuss how these problems might be solved. [40%]

END OF PAPER