

MET3  
MANUFACTURING ENGINEERING TRIPOS PART IIB

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Tuesday 24 April 2018 9.00 to 12.10

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**PAPER 1**

*Answer not more than **four** questions.*

*Answer each question in a separate 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.*

*Write your candidate number **not** your name on the cover sheet.*

**STATIONERY REQUIREMENTS**

8 page answer booklet x 4  
Rough work pad

**SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM**

CUED approved calculator allowed  
Engineering Data Book

**10 minutes reading time is allowed for this paper at the start of the exam.**

**You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.**

- 1 (a)
- (i) Describe the process of injection moulding, including the key components and steps as well as examples of typical applications. [15%]
- (ii) Describe any two quality issues or defects commonly observed in products made by injection moulding. In each case, include a note on the possible underlying causes of the defect. [15%]
- (iii) You are in charge of quality control at a factory where one of the products is a medical implant for spinal surgery. The implant is made by injection moulding with an advanced polymer biomaterial, polyether ether ketone (PEEK). PEEK is a semi-crystalline thermoplastic polymer. A recent batch of products have failed quality control because of a lower than expected mechanical performance.
- Describe three characterisation techniques you would use to study the PEEK. Include in your description a brief note about how each technique works, the properties it can define and the results you may expect to find in this case. [30%]
- (b) (i) Describe in detail what is meant by *Primary Industries* and *Secondary Industries* with relation to the chemical process industry. Include examples and also typical characteristics of each industry type in your description. [15%]
- (ii) Explain why the pharmaceutical industry is considering moving away from using only batch processing for some products. Describe in your answer an alternative approach being explored by the pharmaceutical industry and any advantages it offers. [25%]

- 2 (a)
- (i) Describe two manufacturing systems for additive manufacturing of bulk metal parts. In each case, include in your description example applications and why additive manufacturing is chosen over conventional production processes. [25%]
- (ii) Discuss the challenges in applying metal additive manufacturing to high volume manufacturing. Include in your discussion any potential innovations that could overcome the challenges noted. [25%]
- (b) (i) Discuss similarities and differences between semiconductor manufacturing production methods and those of conventional additive manufacturing. [25%]
- (ii) Describe two examples of emerging technologies that have the resolution of current semiconductor lithography processes and process characteristics of conventional additive manufacturing techniques. [25%]

3 A mobile phone manufacturer currently assembles two models of phones on a manual production line. One particular operation involves the fastening of all components to the inside of the front phone cover using self-tapping torque screws. The production manager has been asked to investigate the use of a robotic fastening cell to replace the current manual operation.

(a) Discuss the pros and cons of different robot types that could be used within the fastening cell. Rank the suitability of each of the robot types discussed. [30%]

(b) The systems integrator building the robotic fastening cell is going to develop an end-effector that can be fitted to the end of a robot. The end-effector will accommodate the operation of a simple electric screwdriver to perform the fastening of the self-tapping torque screws. A diagram of the electric screwdriver can be seen in Fig 1. The electric screwdriver has the following features to support fastening operations:

- a Two forward rotation speeds; slow speed and screw fastening speed.
- b A mechanical motor clutch to limit the torque applied during screw fastening.
- c An output contactor that changes state when the mechanical motor clutch engages.
- d A vacuum port to enable screw pick-up.

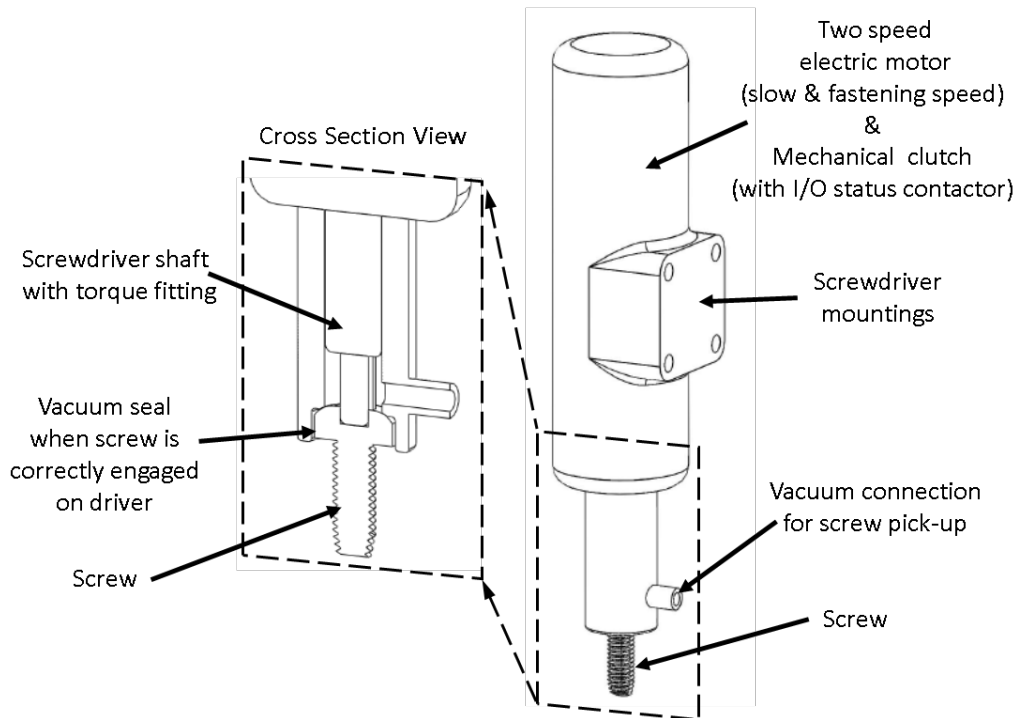


Fig. 1

(i) An end-effector is to be designed to facilitate the operation of the electric screwdriver when mounted onto the robot. Specify the type of actuators and sensors that would be required to perform fastening operations. Indicate how the sensors you select can be used to identify common error conditions. [40%]

(ii) Draw a flowchart that depicts the logic required to control the operation of the robot, end effector and screwdriver when performing all actions required to fasten a screw. Include on the flowchart the logic associated with any error conditions that should be considered. [30%]

4 Polymer food packaging waste is being targeted for reduction in the UK, with discussion of a range of measures that could be put in place. End-of-life plastic is seen as problematic partly because some of it enters the environment as uncontrolled waste, but there is also concern about some of the intended end-of-life routes and processes.

(a) What are the main end-of-life processes that can be used for polymers? Briefly assess their eco-impact. [30%]

(b) What are the difficulties associated with recycling of polymer food packaging? [20%]

(c) How can the global environmental impact of food packaging be assessed? Your answer should include discussion of system boundaries and the balance of factors that should be considered for food packaging. Based on your assessment, what measures should be considered for reducing food packaging waste whilst not compromising its global environmental impact? [30%]

(d) Biodegradable polymers are sometimes promoted as a 'green' packaging solution. To what extent is this justified? [20%]

5 (a) Describe six supply chain risk mitigation strategies. Explain possible unintended consequences of supply chain risk mitigation, using examples. [50%]

(b) Compare and contrast the *traditional* and the *configurational* approach to supply chain risk management. [50%]

6 (a) A furniture manufacturer produces wooden tables and chairs. The profit per table is £6, and profit per chair is £8. The resources the company uses to produce tables and chairs are boards of wood (measured in ft) and labour (measured in hours). It takes 30 ft of wood and 5 hours to make a table, and 20 ft of wood and 10 hours to make a chair. There are 300 ft of wood available per week and 110 hours of labour available per week. The management wants to determine the optimal number of tables and chairs to make per week in order to maximise profit.

(i) Formulate a linear programming model for this problem. [10%]

(ii) Use a graphical approach to describe how the *Simplex Method* of solving a linear programming problem can be used to determine the optimal number of each product to make. What is the corresponding maximum total profit? [20%]

(iii) How would your answer to part (a)(ii) change if the furniture manufacturer wants to sell all of its tables and chairs in sets, consisting of one table and four chairs? Briefly discuss the implications of your answer. [20%]

(b) The furniture manufacturer is currently faced with the question of whether to extend £10,000 credit to a potential new customer, a furniture retailer. The credit manager of the company has three categories for assessing the creditworthiness of a customer: poor, average, and good. However, she does not know into which category this potential customer fits. Experience indicates that 20% of companies similar to this retailer are 'poor', 50% are 'average' and 30% are 'good'. If the credit is extended, the expected loss for 'poor' customers is £1,500. The expected profit for 'medium' customers is £1,000 and for 'good' customers is £2,000. If the credit is not extended, the retailer will turn to another manufacturer.

The credit manager is able to consult a credit-rating agency for the potential customer to be evaluated. Historical data available to the credit manager showed that the credit-rating agency is not always accurate. For customers whose actual credit record is known



to the manufacturer, Fig. 2 shows the percentages that were given each of the credit evaluations by the credit-rating agency.

| Actual credit record of companies known to the manufacturer | Percentage of companies rated in each category by the credit rating agency |         |      |
|---|--|---------|------|
|   | Poor   | Average | Good |
| Poor  | 70%  | 20%     | 10%  |
| Average   | 20%  | 70%     | 10%  |
| Good  | 10%  | 20%     | 70%  |

Fig. 2

- (i) Assuming the credit-rating agency is not used, determine which option should be chosen by the manufacturer. [10%]
  
- (ii) If the credit manager chooses to consult the credit-rating agency, what should be her decision based on the agency's findings? [20%]
  
- (iii) What is the maximum fee that the credit manager should be willing to pay the credit-rating agency for the credit evaluation? [20%]

**END OF PAPER**

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