Version CYB/6

MET3
MANUFACTURING ENGINEERING TRIPOS PART IIB

Wednesday 22 April 2015 9 to 12

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.

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

1 A consumer electronics company is looking to automate the production of a small USB charger. The charger is currently assembled manually and consists of an electronics module enclosed within a two piece plastic moulding as shown in Fig. 1. Three screws are used to secure the electronics module into the lower plastic moulding. Three screws are used to provide electrical continuity from the electronics through to the mains plug pins in the lower plastic moulding. The upper plastic moulding is pushed into place on the lower plastic moulding, snap fitting into place.

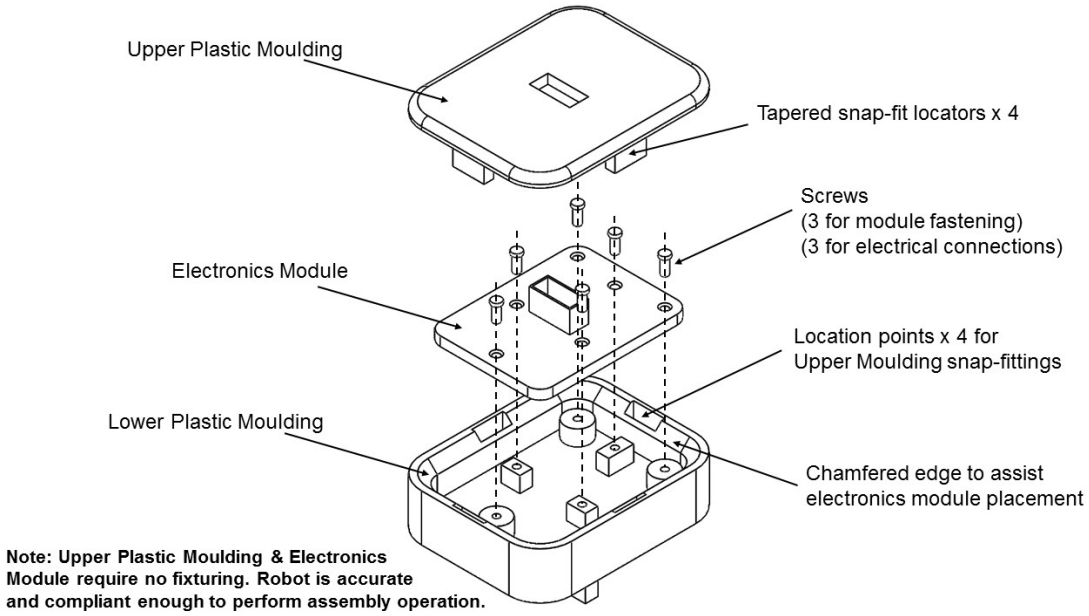

Fig. 1. Exploded assembly drawing of USB mains block charger.

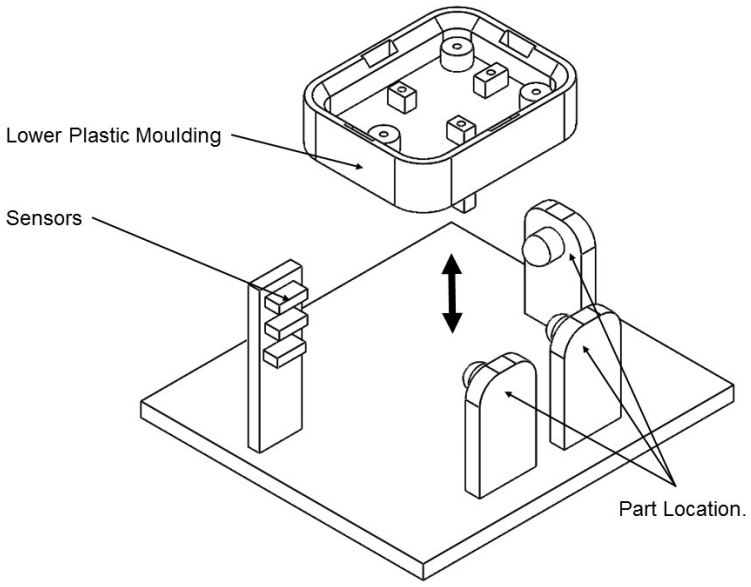

Fig. 2. Proposed assembly fixture (incomplete).

 (cont.

The company has a number of pieces of automation equipment available including one each of the following:

4 Axis SCARA Robot;
5 Axis Anthropomorphic Robot;
Turntable, with two operational positions at 180º;
Electric Screw Driver, with a vacuum system for picking up individual screws;
Bowl Screw Feeder;
Conveyor system with one docking station and several conveyor kitting trays, each holding a set of parts required for the production of one USB charger.

(a) Using the available automation equipment, propose a layout of an automation system that could be used for the assembly of the USB charger and provide a sketch to illustrate your proposal. Discuss the different options you consider for the use of the robots, conveyor system and turntable. [50%]

(b) An assembly fixture is required for locating and holding the lower moulded plastic moulding during the assembly process. An incomplete version of this fixture is proposed in Fig. 2.

(i) Identify and justify additional elements that are required to complete this fixture. [25%]

(ii) In particular, discuss the type and location of sensors required to ensure reliable operations. [25%]

2 (a) Describe three different processes of additive manufacturing ('*3D printing*'). For each process, indicate the range of materials for which it can be used. [40%]

(b) "3D printing .... has the potential to revolutionize the way we make almost everything." (President Barack Obama, 12 February 2013).

Discuss the validity of this statement. In your answer, use your knowledge of the capabilities of conventional manufacturing processes, as well as of additive manufacturing processes, for metals, polymers and ceramics. [60%]

3 (a) Nano-materials have received much interest from industry in recent years. What are nano-materials and what differentiates these materials from conventional materials? Give examples of the different classes of nano-materials to support your answer. [30%]

(b) Manufacturing at the nano-scale offers considerable challenges to the industrial process developer. Describe the two main approaches used to fabricate nano-materials and briefly describe two examples of different processes for each approach. [40%]

(c) A product developer wishes to create a new in-line water filter technology. Their current design relies on mechanical separation using a mesh. Describe a means by which they could employ nano-materials to deliver a new water filtration solution that can be produced in high volumes. Your answer should include details of the following:

- choice of materials;
- materials production method;
- basic system design;
- any commercial issues that they may encounter. [30%]

4 (a) Discuss, using examples, five different ways in which manufacturing companies are servitising. [40%]

(b) A major manufacturer of heavy trucks offers a maintenance service to one of their customers in the mining industry. The company is contemplating four strategies for maintaining the truck engines:

- Strategy 1: No preventive maintenance and repair engines when they fail. This strategy costs nothing to implement. There is a 0.10 probability of a defect arising in the engine leading to subsequent failure, which will require an emergency repair at a cost of £15,000.

- Strategy 2: Take oil samples at regular intervals and perform whatever preventive maintenance is indicated by the oil analysis. This costs £50 to implement, and has no effect on the probability of defect occurrence compared to Strategy 1. However, there is a 0.70 probability that the oil analysis will correctly identify the existence of a defect if it exists, resulting in a preventive maintenance at a cost of £2,000. If the oil analysis does not identify the existence of a defect, it will subsequently lead to engine failure, which will require an emergency repair at a cost of £15,000. On the other hand, if there is no defect, there is a 0.20 probability that the oil analysis will erroneously indicate that there is a defect, resulting in unnecessary maintenance at a cost of £1,200.

- Strategy 3: Change engine oil at regular intervals and repair engines when they fail. This costs £200 to implement, but reduces the probability of defect occurrence to 0.04. The defect will lead to subsequent failure of the engine, which will require an emergency repair at a cost of £15,000.

- Strategy 4: Change engine oil at regular intervals and take oil samples at regular intervals, performing maintenance repairs as indicated by the oil analysis. This costs £250 to implement and results in the same probability of defect occurrence as with strategy 3. The reliability of the oil analysis and subsequent outcomes are the same as given in strategy 2.

For the most cost-effective solution, which of the four strategies should the company adopt for maintaining the truck engines? Explain the rationale for your answer. [60%]

5 You work for an automation equipment provider as a project engineer. Your job requires you to agree automation system specifications with customers, as well as project time-lines and system test plans with the project team.

(a) What are the key project milestones that should be considered in the development, integration and delivery of a typical automation project? In each case, note which project organisation is responsible for each milestone and note any interdependencies. [40%]

(b) (i) Describe the purpose of a *functional specification*. [15%]

(ii) What is to be included in the functional specification? [10%]

(c) As part of this new automation development, a series of tests is to be carried out.

(i) Describe what is meant by *unit tests* for the new development. [15%]

(ii) What additional testing needs to be done before the system is ready for site testing and why? [20%]

6 (a) Life Cycle Analysis (LCA) and Eco-Audit can both be used to assess environmental impact.

(i) What information do the two tools provide as outputs? Compare the scope, applicability and limitations of LCA and Eco-Audit with specific reference to an electric kettle. [30%]

(ii) Briefly outline how LCA and Eco-Audit should be carried out. What information is required? [15%]

(iii) With reference to the use of LCA for the production of biodiesel, outline the meaning and significance of the terms *system boundary* and *allocation*. [10%]

(b) Explain how you would use an Eco-Audit to make recommendations on how to reduce the environmental impact of a refrigerator. Give a prioritised list of proposals to achieve this, justifying your answer. What assumptions are made in performing the analysis? [45%]

END OF PAPER