Version POK/3

EGT2
ENGINEERING TRIPOS PART IIA
EGT3
ENGINEERING TRIPOS PART IIB

Thursday 2 May 2019 2 to 3.40

Module 4C4

DESIGN METHODS

*Answer not more than **three** questions.*

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
Single-sided script paper

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 An existing simple printer design allows the user to print by connecting the printer to a computer via a Universal Serial Bus (USB) port. The printer draws power from an AC mains electrical socket. The printer has a manual paper feed, status LED indicators and buttons for turning it on and off and for printing a test page.

(a) Provide a solution-neutral problem statement for the design of the printer. [10%]

(b) Identify the overall function structures, including their functional elements and the flows of energy, materials and signals. [40%]

(c) Distill a modular product architecture for the printer by modularising the function structures identified in (b). [20%]

(d) A competitor has introduced a new printer which allows a wireless connection to the computer and contains a paper magazine, allowing the printer to print multiple pages without manual loading. Carry out a competitive analysis against this printer and identify solution principles and conceptual designs that may ensure a redesign of the original printer can result in a competitive product. [20%]

(e) Discuss briefly the relationship between the technology s-curve and the product architecture of a competitive printer design. [10%]

2 A factory manufactures bicycle tyres.

(a) The probability density that a tyre fails at time t during its useful lifespan is:

$$f(t) = (a + bt) \exp\left(-at - \frac{b}{2}t^2\right)$$

where a and b are parameters.
Derive the hazard function for this distribution. [30%]

(b) Is the hazard function found in (a) reasonable? Explain your reasoning, including any assumptions of parameter values. [10%]

(c) Due to an undiscovered quirk in the manufacturing process, a subset of the bicycle tyres have a uniform probability density of failure at time t during their useful lifespans. Derive the hazard function for this distribution. [20%]

(d) Briefly discuss the reliability implications of the hazard function in (b) compared to the hazard function in (c), including any assumptions of parameter values. [10%]

(e) A student purchases a bicycle tyre made in the factory that manufactures the above mentioned tyres. Derive an expression for the probability of failure of the bicycle tyre in time t due to a puncture from a nail on the road. Explain your reasoning. [30%]

3 A large parcel processing plant is considering a CCTV surveillance system to monitor for suspicious activity. The proposed solution involves a single operator seated in front of three displays with several concurrent CCTV feeds presented on the individual displays. To assist the operator a machine learning algorithm is to be used which may automatically identify suspicious activities and alert the operator.

(a) Devise a solution-neutral problem statement given the provided problem context. [10%]

(b) Write a requirements specification with eight key requirements for the proposed solution. [30%]

(c) Devise a verification cross-reference matrix for the requirements specification identified in (b). [20%]

(d) Identify five factors which could influence operator error in the proposed system. Explain your reasoning. [20%]

(e) Propose a validation strategy for the proposed solution, taking into account the requirements specification from (b), the verification cross-reference matrix from (c) and factors influencing operator error in (d). [20%]

4 A company has designed an automatic fall-detection system for elderly patients living at home. It consist of a wearable device in the form of a bracelet worn by the user. The bracelet uses a set of sensors to estimate the probability a fall occurred. If the estimated probability is above a preset threshold the bracelet sends an alarm signal via a dedicated router installed in the user's home. This signal is then relayed across the Internet to a team of operators. The request is queued and relayed to the next available operator. This operator is then responsible for assessing the severity of the fall by attempting to contact the user, and, if necessary, send someone over to the user's house to investigate.

(a) Briefly describe the roles of system mapping and risk assessment in risk management. [10%]

(b) Map the above system and identify the overall function along with its system boundary. Explain your approach to system mapping. [30%]

(c) Excluding fault trees, suggest three appropriate methods for identifying the risks in the above system. Explain your choices by briefly explaining how they would be applied to the above system. [30%]

(d) Draw a fault tree highlighting the relevant causes of failure that may lead to unsuccessful operation of the system. [30%]

END OF PAPER

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