EGT2
ENGINEERING TRIPOS PART IIA
EGT3
ENGINEERING TRIPOS PART IIB

Monday 8 May 2017   2 to 3.30

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
Supplementary page: blank copy Fig. 2 for Question 3
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 The manufacturing process for making aluminium beverage cans involves stamping flat circular blanks from a coil of aluminium sheet, before deep-drawing and ironing each blank into a can shape. The stamped blanks each have a diameter of 140 ± 0.1 mm. The blanks are arranged on the aluminium sheet in a repeating grid pattern as shown in Fig. 1, with 150 ± 0.1 mm between the blank centres.

Assume that all probability distributions are normal and independent, and that the range from minimum to maximum is equivalent to six standard deviations. Table 1 shows equations for combining probabilities.

(a) Define the meaning of *margin of safety* and show, with a sketch, how the *probability of failure* can be determined by combining distributed variables into a single *probability density* for the margin of safety. [20%]

(b) The stamping tool requires a minimum clearance of 9.9 mm ± 0.1 mm between the edges of any two blanks to allow a clean cut to be made. Calculate the proportion of blanks which will be damaged during the stamping process due to insufficient clearance. [20%]

(c) The ideal packing ratio of circles in a hexagonal lattice equals $\pi/(2\sqrt{3}) \approx 90.7\%$. However in real stamping processes the packing ratio is much lower due to the required stamping clearance and the finite width of the aluminium sheet. A manufacturer wants to ensure that no more than 25% of their aluminium sheet is scrapped during stamping. Their stamping machine is able to punch a row of ten blanks perpendicular to the direction of the uncoiling aluminium sheet, and offset the punches to produce the repeating grid pattern.

(i) Calculate the area of a suitable repeating section of the aluminium sheet and compare this to the area of the punched blanks to find the actual packing ratio. Using probability density functions, calculate what proportion of stamping runs will meet the 25% target for aluminium scrapped. [40%]

(ii) Suggest alternative process designs and product designs to reduce the amount of scrap aluminium created during the stamping process, and comment on their effectiveness. [20%]

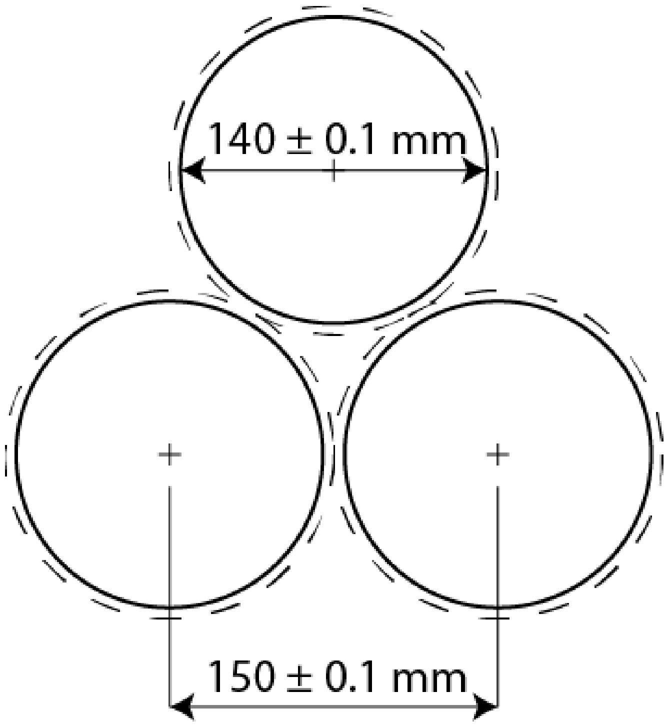

Fig. 1

y	μ_y	σ_y^2
$x + a$	$\mu_y + a$	σ_x^2
ax	$a\mu_x$	$a^2\sigma_x^2$
$a_1 x_1 + a_2 x_2$	$a_1\mu_1 + a_2\mu_2$	$a_1^2\sigma_1^2 + a_2^2\sigma_2^2$
$x_1 x_2$	$\mu_1\mu_2$	$\mu_2^2\sigma_1^2 + \mu_1^2\sigma_2^2$
x_1/x_2	μ_1/μ_2	$(\mu_2^2\sigma_1^2 + \mu_1^2\sigma_2^2)/\mu_2^4$

Table 1: Equations for combining probabilities, where y is a function of independent variables x_n, a is a constant, μ is the mean and σ is the standard deviation.

2 A product currently consists of three electronic components C_1, C_2 and C_3, with corresponding individual probabilities of failure P_1, P_2 and P_3 and individual reliabilities of the form $R_i = (1 - P_i)$.

(a) Derive an expression for the *reliability* of the product if the components are wired in *series*. [10%]

(b) Derive an expression for the *reliability* of the product if the components are wired in *parallel*. [10%]

(c) The hazard function is defined as $\lambda(t) = {}^{f(t)}/_{R(t)}$, where $f(t)$ is the probability density function and $R(t)$ is the reliability function. Show that the hazard function is constant when the time t before a failure is exponentially distributed. Comment on the significance of this result when determining the failure rate of a product. [30%]

(d) Assume each component has a constant failure rate and the probability of a failure of an individual component is independent of the other components and $P_1 = P_2 = P_3$. The mean time between failures (*MTBF*) for an individual component is 100,000 hours. Calculate the probability of the product failing within a 5-year warranty period when:

(i) all three components are wired in series;

(ii) all three components are wired in parallel. [40%]

(e) State the definition of *value* in value engineering and calculate the gain in *value* for the parallel wiring configuration, compared to the series configuration, assuming identical component and assembly costs. [10%]

3 A Multiple Domain Matrix (MDM) is shown in Fig. 2 and represents a system with seven tasks being carried out by four people.

(a) Rearrange the tasks of the Design Structure Matrix (DSM) into suitable clusters. [30%]

(b) Draw a task diagram for the DSM showing the clustered tasks. Then add the interactions shown in the Domain Mapping Matrix (DMM) to your diagram. [40%]

(c) Suggest a team configuration to complete the person DSM. Explain your choices. [20%]

(d) Explain the difference between structural and behavioural system mapping diagrams used in risk analysis, and provide examples of each. [10%]

A blank copy of Fig. 2 is attached to the back of this paper. It may be detached, annotated and handed in with your answers.

	task 1	task 2	task 3	task 4	task 5	task 6	task 7	person 1	person 2	person 3	person 4
task 1					X	X					
task 2	X		X	X			X				
task 3		X		X			X				
task 4		X	X		X		X				
task 5				X		X					
task 6	X				X		X				
taks 7		X		X							
person 1	X					X					
person 2				X	X						
person 3		X	X	X							
person 4		X	X				X				

Fig. 2

4 People operating in certain areas run the risk of severe brain damage due to blast waves caused by high explosives. A particular problem in triage is to diagnose quickly and accurately whether a person without visible physical injuries requires immediate medical attention due to the risk of unobservable brain trauma. Due to resource constraints it is not viable to give full medical attention to all people in the vicinity of an explosion. Your company has been contracted to design a wearable system worn by users in these high risk areas. The wearable system will sense blast waves and based on this data estimate the risk of brain trauma on the wearer and communicate this status to medical personnel on site.

(a) Suggest one type of wearable sensor suitable for estimating the damage caused by a blast wave on the user. Motivate your answer. [10%]

(b) State the overall function of the wearable device using a solution-neutral problem statement. [10%]

(c) List five critical requirements for the wearable device. [25%]

(d) Discuss how the requirements set out in (c) can be verified. [25%]

(e) Identify solution principles that address the requirements in (c) and describe the design of a system that addresses the design brief set out in the question. [30%]

END OF PAPER

Version JMC/3 Candidate Number:

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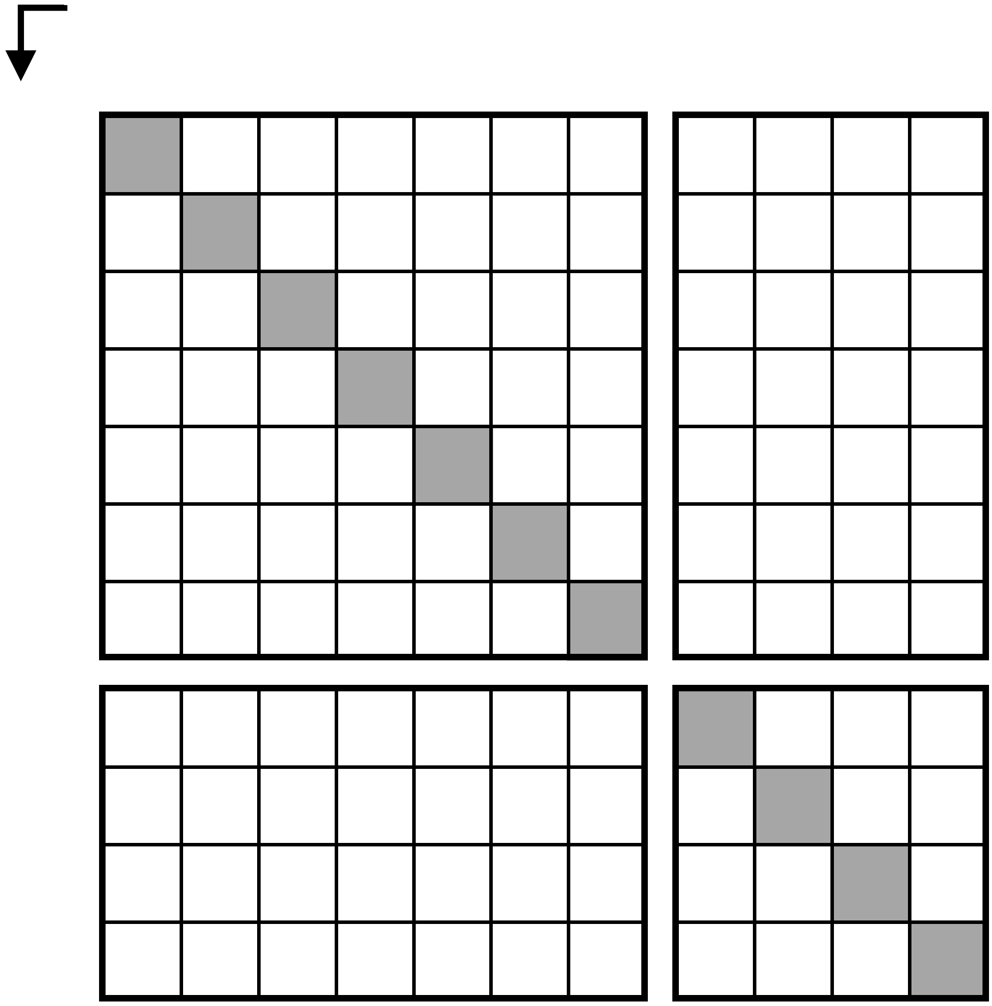
Monday 8 May 2017, Module 4C4, Question 3.



Blank copy of Fig. 2 for Question 3.