EGT2
ENGINEERING TRIPOS PART IIA
EGT3
ENGINEERING TRIPOS PART IIB

Thursday 28 April 2016   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
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 novel type of cylindrical cork is used to seal a bottle of champagne as shown in Fig. 1. The neck of the bottle has an inner radius of 10 mm $\pm$ 0.1 mm and the pressure difference between the inside and outside of the bottle is 5 atmospheres $\pm$ 1 atmosphere. The force required to overcome friction between the cork and the bottle is equal to 275 N $\pm$ 20 N, and is independent of the internal diameter of the bottle neck. Table 1 shows equations for combining probabilities.

(a) Define the meaning of the terms *safety-factor* and *safety-margin* and state how these concepts may be applied to the problem of ensuring the cork stays in the bottle. [20%]

(b) Calculate the safety-factor for the cork staying in the bottle for the *nominal case* and the *worst case*. [20%]

(c) A company fills and seals the bottles in batches of one thousand. Calculate the number of bottles which will fail because of the cork escaping from the bottle. Assume that all probability distributions are normal, and that the range from minimum to maximum is equivalent to six standard deviations for the inside radius of the bottle neck, and two standard deviations for the remaining variables. [20%]

(d) A person using a standard direct-pull corkscrew is capable of applying a force of 150 N $\pm$ 10 N when removing the cork from the bottle neck. Assume that the range from minimum to maximum for the direct-pull force is equivalent to two standard deviations. Calculate the proportion of bottles which cannot be opened using this corkscrew. [20%]

(e) An engineer proposes to design a new corkscrew. Calculate the pull-force required, to the nearest 1 N, which would allow 99% of corks to be removed from their bottles. Comment briefly on possible design changes to the standard corkscrew which would allow this additional force to be achieved. [20%]

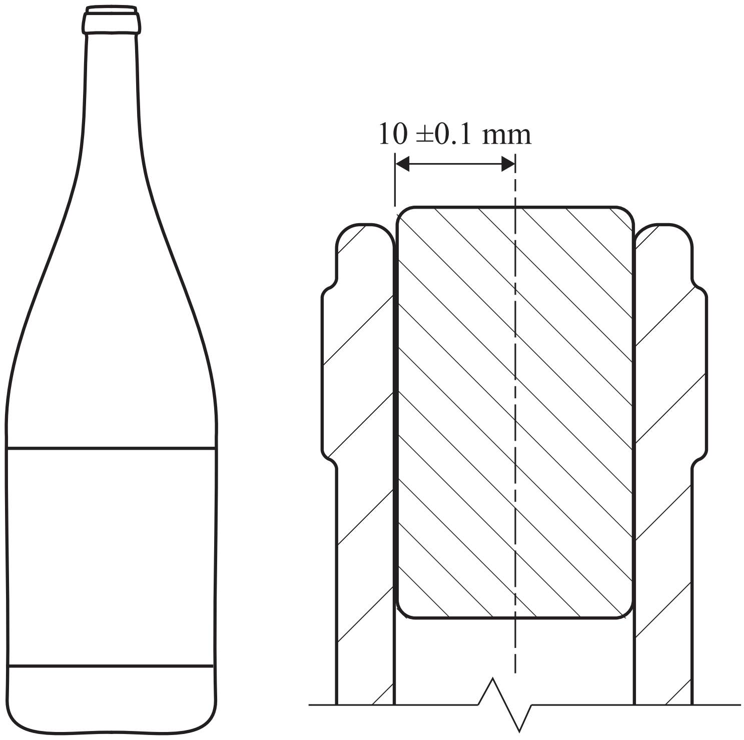

Fig. 1

y	μ_y	σ_y^2
$x + a$	$\mu_x + a$	σ_x^2
ax	$a\mu_x$	$a^2\sigma_x^2$
$a_1x_1 + a_2x_2$	$a_1\mu_1 + a_2\mu_2$	$a_1^2\sigma_1^2 + a_2^2\sigma_2^2$
$x_1\, x_2$	$\mu_1\, \mu_2$	$\mu_2^2\sigma_1^2 + \mu_1^2\sigma_2^2$
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 probabillities, where y is a function of independent variables x_n, a is a constant, μ is the mean and σ is the standard deviation.

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2 You are part of a design team tasked with designing a new concept for a mobile phone. The design brief states that the mobile phone must feature a large capacitive touchscreen on the front which is protected by a cover which, when closed, completely covers the large capacitive touchscreen. The cover must provide the user with the ability to view: the current time, the current local weather, and recent call information. This information must be available to the user when the cover is closed and fully covers the capacitive touchscreen. In addition, the cover must allow the user to call a few pre-programmed telephone numbers without the need to open the cover.

(a) Explain how systematic use of creative methods, for example brainstorming, can facilitate the identification of different designs of the cover. [20%]

(b) Describe the difference between a product's sub-functions and a product's components. [10%]

(c) Discuss solution principles and present a design solution, which may include a sketch, for a highly *modular* cover that can perform all the functions set out in the design brief. [25%]

(d) Discuss solution principles and present a design solution, which may include a sketch, for a highly *integral* cover that can perform all the functions set out in the design brief. [25%]

(e) Comment on the strengths and weaknesses of the design solutions that you have presented in (c) and (d). [20%]

3 A UK consortium proposes to design and build a full-scale demonstration plant using carbon capture and storage (CCS) technology to trap carbon dioxide (CO_2) emissions from a fossil-fuel based power station and store them underground permanently, as a mitigation strategy against climate warming. The proposed CCS process involves three main stages:

Capture—extraction of a pure stream of CO_2 from the combustion gases. This is a complex but well-understood technology which involves passing the exhaust combustion gases through an amine chemical absorber tower to produce a pure stream of CO_2.

Transport—compression and liquidisation of CO_2 gas ready to be transported by pipeline to an offshore storage facility. The technology for transporting CO_2 by pipeline is already viable, but obtaining permissions to route pipelines overland can be difficult.

Storage—permanent storage of CO_2 gas in an offshore reservoir. Injecting CO_2 gas into reservoirs is practised as a means to boost oil recovery, however the technology for long-term secure storage is still unproven.

All three stages are expensive, requiring large capital investment and financial subsidies from the UK Government. In addition, the capture and compression of CO_2 gas is estimated to increase the fossil-fuel needs for a CCS power plant by up to 40% and raise the cost of electricity production by up to 90%. The consortium appreciates that there is some considerable risk in developing this project and deploying the CCS technology in an established energy market and aims to utilise good risk management practice during the project delivery.

(a) Describe the elements of good risk management practice that will increase the consortium's chance of successfully delivering the CCS demonstration project. [40%]

(b) Sketch a fault tree highlighting events that may lead to the unsuccessful operation of the CCS demonstration plant. [30%]

(c) The consortium is considering the use of three risk assessment techniques: HAZOP, FMEA and FTA. Describe each technique and comment on its suitability for assessing risk in each of the three CCS technology stages: capture, transport, and storage. [30%]

4 Your company is designing a product that allows literate non-speaking individuals with motor disabilities to communicate with other people using a physical on/off switch, for instance, by moving an eye-brow to trigger a switch or by using a limb to push a large button. A series of single-switch signals are processed by a computer system to generate synthetic speech. The disabled end-users can only use a single-switch interface but do not have any hearing or eye-sight problems. They also have full cognitive functionality.

(a) Use a solution-neutral problem statement to describe the overall function of the product. [10%]

(b) List the key requirements for the product. [20%]

(c) Identify solution principles that address the requirements in (b), and describe a possible product design. [40%]

(d) Describe the difference between verification and validation. [10%]

(e) Discuss appropriate verification and validation strategies for the product. [20%]

END OF PAPER