ENGINEERING TRIPOS PART IIA
ENGINEERING TRIPOS PART IIB

Tuesday 4 May 2010 2.30 to 4

Module 4C4

DESIGN METHODS

Answer not more that ***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.*

There are no attachments.

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

pjc02

1 The design department of a large well-established furniture company is trying to decide between two competing concepts (Modulon and Integron) for a new office chair that their firm will manufacture. The two designs are primarily distinguished by the degree of architectural modularity that they exhibit (see Fig. 1).

The firm's marketing department have provided the following information:

The proportion of users requiring a certain type of caster (i.e. either hard or soft) varies between different geographies. Within a given geography this proportion changes with the prevailing fashions of interior design (i.e. whether offices are carpeted or not). The firm will initially launch the chair in just one size and fabric, with other options being considered once the market response to the chair has been assessed. The size and weight of the chair are important factors in determining transportation costs, and these transportation costs do in turn influence the retail price for the chair.

Acting as a design consultant, you have been asked to help the firm consider the implications of each design.

(a) For each design construct a diagram that shows the mapping between the physical elements and the functional elements. [20%]

(b) Describe the relative benefits of each design's architecture with respect to:

(i) The design process; [20%]

(ii) The manufacturing and distribution processes; [20%]

(iii) Future opportunities to offer product variety (at launch); [20%]

(iv) Future opportunities to change the product (during life). [20%]

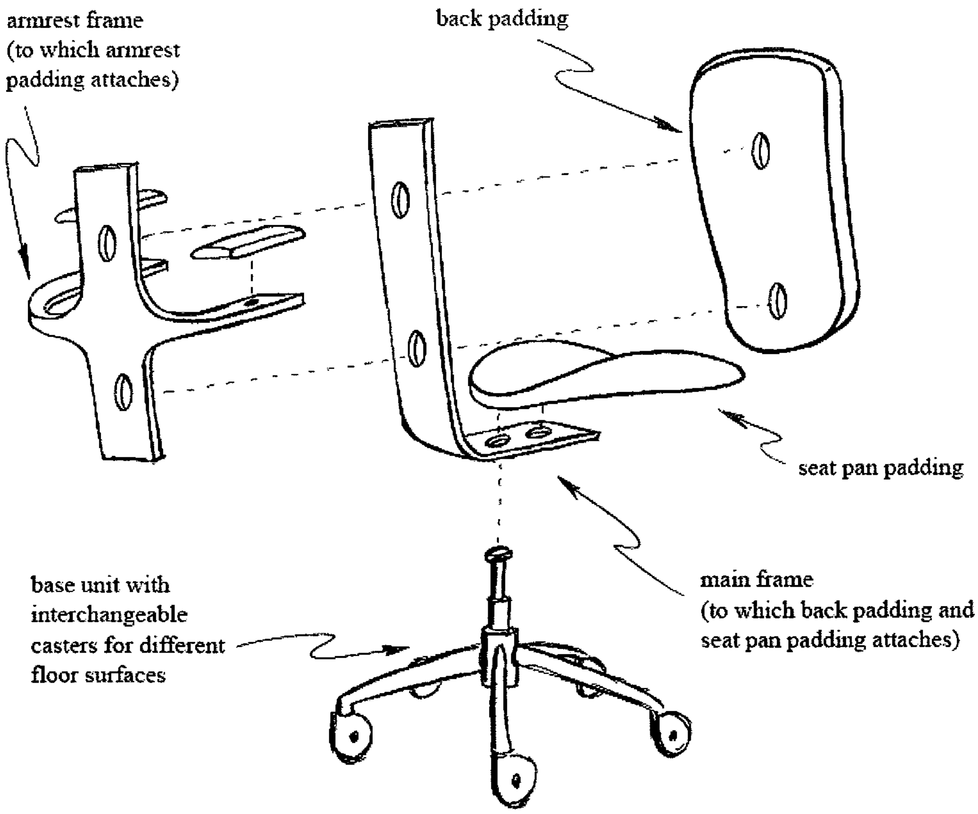


Fig 1a. Modulon office chair concept sketch.

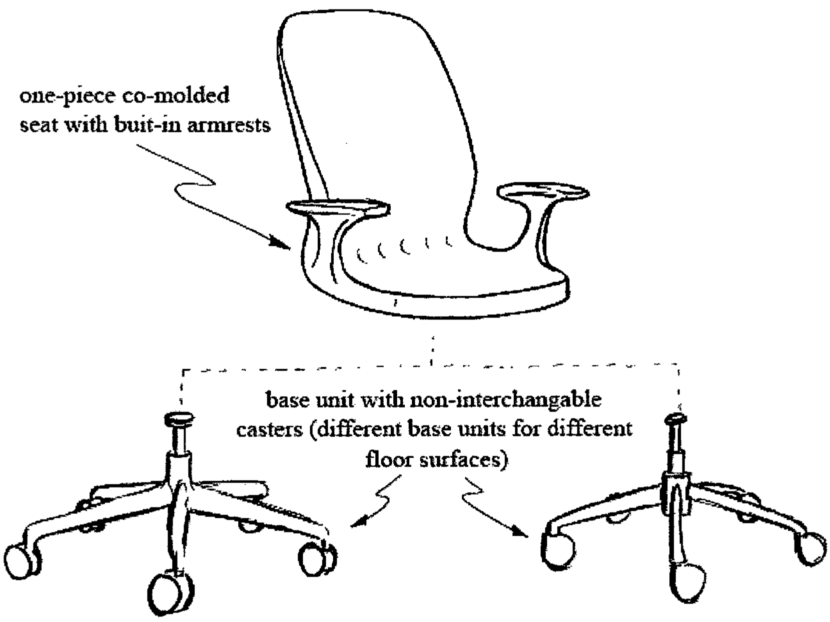


Fig 1b. Integron office chair concept sketch.

2 A simplified schematic diagram of an aircraft undercarriage control system is shown in Fig. 2. At the instant shown, the system is in the 'stowed' configuration, which is suitable for flight but not for landing. To deploy the undercarriage for landing, the pilot pulls up on lever A (as indicated). This action moves the other end of the lever (point B) to the left and extends encoder C. This sends an electrical signal to actuator D causing it to retract. This rotates wheel F into the 'deployed' position (as indicated). As the undercarriage deploys, a pair of magnetic tags attached at G move away from a pair of proximity sensors at H. Each proximity sensor sends a signal to the processing box at I. If (and only if) both signals indicate that the undercarriage is deployed, then a signal is sent to the pilot's display at J causing the 'stowed' bulb to dim, and the 'deployed' bulb to illuminate.

The only information that the pilot has about the position of the undercarriage is the position of the lever and the display reading. The worst case scenario is when the pilot is unaware that the undercarriage has not deployed despite pulling the lever. This is only possible when all three of the following conditions are observed: (i) lever A is in the 'deployed' position; (ii) the undercarriage has failed to deploy; (iii) the pilot is unaware that the undercarriage has failed to deploy.

The components of the system have the following characteristics: a mechanical disconnect at B would cause encoder C to retract (spring loaded); a mechanical disconnect at E would cause the undercarriage to retract to the stowed position (spring loaded); a break in wire CD would cause actuator D to extend; a break in wire IJ would cause the display to read 'stowed'; if either (or both) of the proximity sensors sends a 'stowed' signal to the control box, the control box is set to send a 'stowed' signal to the display. The signals between components only flow in the directions indicated.

Component testing shows that for any single attempt to deploy the undercarriage, the likelihood of component failure is as follows: mechanical disconnect at B, $p = 3\times10^{-6}$; mechanical disconnect at E, $p = 1\times10^{-6}$; a break in wire CD, $p = 6\times10^{-6}$; a break in wire IJ, $p = 2\times10^{-5}$; a proximity sensor erroneously sends the 'deployed' signal (despite being close to the tag at G), $p = 3\times10^{-3}$; the signal processing box erroneously sends the 'deployed' signal (despite one or both of its input signals reading 'stowed'), $p = 1\times10^{-6}$. Human factors testing shows that the likelihood that a pilot will fail to notice that the display reads 'stowed' (when the lever is in the 'deployed' position) is $p = 1\times10^{-2}$. The likelihood of all other possible failures may be considered negligible. Only the situation of the pilot coming in to land the aircraft need be considered.

(a) Assuming that the lever has been set to deploy the undercarriage, draw a fault tree diagram for the system with 'undercarriage fails to deploy' as the top level event. [10%]

(b) Assuming that the lever has been pulled up and the undercarriage has failed to deploy, draw a fault tree diagram for the system with 'pilot unaware that undercarriage has failed to deploy' as the top level event. [40%]

(c) Determine the likelihood that the worst case scenario occurs (i.e. that the pilot is unaware that the undercarriage has not deployed despite pulling the lever). [10%]

(d) With respect to the worst case scenario, describe five different ways in which the system could be modified or added to. Prioritise your answers, and, where possible, quantify the improvements made. [40%]

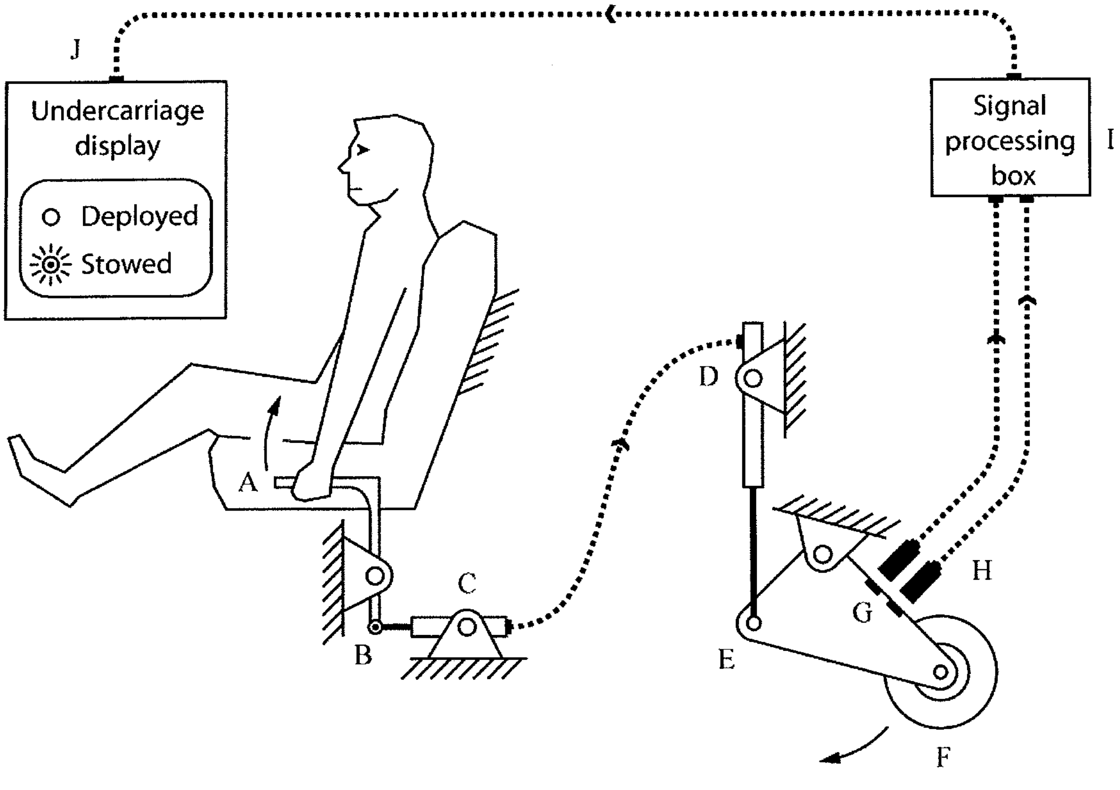
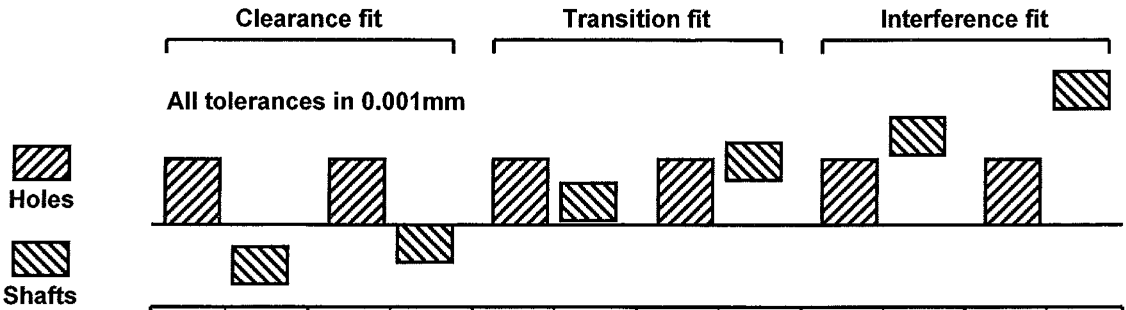


Fig 2. Schematic of aircraft undercarriage control system

3 British Standard BS4500 describes tolerances required for fitting a shaft into a hole. An extract of BS4500 for a 50 mm hole is shown below.



H7	g6	H7	h6	H7	k6	H7	n6	H7	p6	H7	s6
+30	-10	+30	0	+30	+21	+30	+39	+30	+51	+30	+72
0	-29	0	-19	0	+2	0	+20	0	+32	0	+53

The first two entries in the table define clearance fits (where the shaft will always fit in the hole), the next two define transition fits (where the shaft might fit in the hole) and the final two define interference fits (where the shaft will not fit in the hole).

In order to assemble a transition or interference fit the hole (assembly) can be heated to provide a clearance fit which will shrink to the required fit on cooling.

You may assume that the range from minimum to maximum represents six standard deviations and that a 'fit' is achieved when a shaft is smaller than a hole.

(a) For the two transition fits, calculate the probability that a randomly selected shaft will not fit in a randomly selected hole with no pre-heating. [30%]

(b) If the hole dimensions increase by 0.025% for every 1 minute of heating, calculate the time required, for each of the interference fits, to heat the hole such that 98% of the shafts will fit without further heating. [50%]

(c) The inner race of a rotary bearing is to be assembled with an interference onto a shaft and the outer race with an interference fit into a housing. Describe possible assembly approaches for the housing, bearing and shaft. [10%]

(d) Comment on the validity of the definition of 'fit' above and describe how a more pragmatic definition might change the results of (a) and (b). [10%]

4 Following a prolonged cold spell during the recent winter months a lawnmower manufacturer has decided to develop a de-icing machine for use by local councils to remove snow and ice from pavements. You have been tasked to develop a concept for such a device.

(a) Abstract the task to at least four levels and prepare an appropriate solution-neutral problem statement. [10%]

(b) List six key requirements for your new product. [10%]

(c) Establish the overall function for the product. Identify up to four sub-functions and arrange these in a product or process function structure as appropriate. [20%]

(d) Describe, with detail of key features, a concept for a new product. [40%]

(e) Describe how the new product might be proven to be fit for purpose. [20%]

END OF PAPER