

OLLSCOIL NA hÉIREANN, GAILLIMH  
NATIONAL UNIVERSITY OF IRELAND, GALWAY

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Summer Examinations 1999

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B.E. Degree : Industrial Engineering & Information Systems

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*IE426:Quality*

Dr. Wright,  
Prof. O'Kelly,  
Dr. Sheil.

Time allowed: *Three* hours

Attempt *four* questions: any *two* from A1, A2, A3, A4;  
any *two* from B1, B2, B3, B4.

*Cambridge Statistical Tables* supplied.

*Mathematical('log') Tables* available

Tables for determining Control Chart Parameters appended.

## A1.

State what the following terms mean to you:

(i) *Shewhart Control Chart* (ii) *rational subgroup*

[4 marks]

Differentiate between *probability limits* and *3-sigma limits* for Shewhart charts. [3 marks]

When a measurable characteristic of produced parts is being monitored/controlled, typically two charts, an  $\bar{X}$ -chart and an R-chart, are operated in tandem. Why? [2 marks]

Draft a general form to be used to record data for, and plot such charts. [4 marks]

The data below was collected from a process manufacturing power supplies. The variable of interest is output voltage; the subgroup size 5. Find centerlines, warning and action *probability* limits for  $\bar{X}$  and R charts to control future production. [12 marks]

Subgroup	$\bar{X}$	R	Subgroup	$\bar{X}$	R	Subgroup	$\bar{X}$	R
1	103	4	9	104	3	17	105	3
2	102	5	10	103	5	18	106	5
3	104	2	11	106	4	19	102	2
4	105	11	12	105	3	20	105	4
5	104	4	13	105	4	21	103	2
6	106	3	14	103	2	22	101	4
7	102	7	15	102	3	23	104	5
8	105	2	16	105	4	24	106	4

## A2.

Explain what is meant by the *ARL* of a control chart.

[2 marks]

If  $P$  represents the probability that a point will plot inside the control limit(s) on a control chart, show that the corresponding value for the *ARL* is  $1/(1 - P)$  [6 marks]

Under what circumstances would you employ a *p-chart*? [2 marks]

A *p-chart* with control limits at 0.005 and 0.075 is being used to control a process. The chart is based on subgroups of 100 items. When the process is in control, the proportion of nonconforming product is 0.04. [Hint:  $Bi(n, p) \rightarrow Poi(np)$  ]

(i) Find/estimate the probability of false alarms in this case. [3 marks]

(ii) If the process proportion nonconforming "slips" to 0.05, what is the probability that the next point plotted will fall outside the control limits. [3 marks]

Hence determine the *ARL* to detection of this slip. [2 marks]

(iii) Sketch an *OC-curve* for this chart. [8 marks]

**A3.**

A CUSUM chart is constructed by plotting  $S_r = \sum_{i=1}^r (\bar{X}_i - m)$ ;  $r = 1, 2, 3, \dots$

versus  $r$ , where the  $\bar{X}_i$ 's are sample/subgroup means and  $m$  is a fixed reference value.

- (i) Why must care be exercised when choosing  $m$  and scales for the plot axes? [1 mark]  
 (ii) Explain briefly how to visually interpret CUSUM plots. [3 marks]

Let the subgroup size be  $n$ ; the process standard deviation for  $X$  be  $\sigma$  and let the chart be scaled so that one unit on the  $r$ -axis is equal to  $\sigma/\sqrt{n}$  units on the CUSUM axis.

- (iii) If the current process mean for  $X$  is  $m + \sigma/\sqrt{n}$ , show that "on average"  $S_r$  will plot as a line, at an angle of  $45^\circ$  to the  $r$ -axis. [3 marks]  
 (iv) What would be the average slope of the plot if the mean was  $m + 2\sigma/\sqrt{n}$ ? [3 marks]

Now, describe briefly how to construct and use a CUSUM *key*. [3 marks]

Samples of size five were drawn at regular intervals from the output of a production process. The sample averages for a critical parameter were as shown below. Prepare and analyze a CUSUM plot, using the *5-10-10 Rule*, if appropriate. [12 marks]

10.45, 10.55, 10.37, 10.64, 10.95, 10.08, 10.50, 10.87, 11.25, 11.46,  
 11.39, 11.69, 11.51, 11.28, 11.38, 11.25, 11.63, 11.88, 11.46, 11.67

**A4.**

Why undertake Gage Capability Studies? [2 mark]

Define: (i) Gage Repeatability, (ii) Gage Reproducibility, (iii) the P/T Ratio [6 marks]

Two operators twice measure each of 10 parts, using a particular gage. The resulting data is shown below.

Part Number	Operator A		Operator B	
1	50	49	50	48
2	52	52	51	51
3	53	50	54	52
4	49	51	48	50
5	48	49	48	49
6	52	50	52	50
7	51	51	51	50
8	52	50	53	48
9	50	51	51	48
10	47	46	46	47

- (iv) Are both operators consistent in their use of the gage? [4 marks]  
 (v) Estimate gage repeatability, gage reproducibility and  $\sigma_{\text{gage}}$ . [10 marks]  
 (vi) The specification on the dimension measured is  $50 \pm 10$ . Is the gage *capable*? [3 marks]

## B1.

Write short(single sentence) 'definitions' for each of the following, all of which relate to Experimental Design/Analysis:

*Factorial Experiments, Replication, Randomisation, Main Effects, Residuals.*

[5 marks]

By writing  $[y_{ij} - \bar{y}_{..}]$  as  $[(y_{ij} - \bar{y}_{i.}) + (\bar{y}_{i.} - \bar{y}_{..})]$ , show that

$$\sum_{i=1}^a \sum_{j=1}^n [y_{ij} - \bar{y}_{..}]^2 = n \sum_{i=1}^a [\bar{y}_{i.} - \bar{y}_{..}]^2 + \sum_{i=1}^a \sum_{j=1}^n [y_{ij} - \bar{y}_{i.}]^2$$

[4 marks]

and state the significance of this result.

[2 marks]

Hence, noting that

$$y_{ijk} - \bar{y}_{...} \equiv (\bar{y}_{i..} - \bar{y}_{...}) + (\bar{y}_{.j.} - \bar{y}_{...}) + (\bar{y}_{ij.} - \bar{y}_{i..} - \bar{y}_{.j.} + \bar{y}_{...}) + (y_{ijk} - \bar{y}_{ij.})$$

write out the decomposition of the Total Corrected Sum of Squares( $SS_{tot}$ ) which applies when testing for main effects and a possible interaction between factors A(at a levels) and B(at b levels) - assuming n replicates of a full factorial design.

[4 marks]

An experiment was conducted to investigate the effect of furnace temperature and dwell time on the average 'fallout' from a process producing a carbon product. Each factor was considered at two levels, a 'low' level and a 'high' level and four batches of product were produced/tested for each factor level combination. The resulting data are presented below. What practical conclusions/recommendations can be drawn from this experiment?

Temp. Time		'fallout' (%)				Totals
low	low	8.2	8.9	2.9	4.4	24.4
high	low	17.2	14.0	12.4	12.5	56.1
low	high	5.9	4.9	5.1	4.2	19.7
high	high	31.0	33.9	26.3	29.9	121.7

[10 marks]

## B2. Answer any five of (a) to (f) below.

[5 marks each]

- Outline the role of *metrics* in Benchmarking.
- When instituting *Quality Cost Programs*, it is important not to be too ambitious. Why?
- A well structured *Internal Quality Audit* program can contribute positively to an organisation's TQM endeavours. Elaborate
- List any **five** characteristics of 'Company Culture' in TQM organisations.
- Develop a *checksheet* to facilitate collection of 'stats' at a sporting event of your choice, e.g. a football game, a day's fishing, a chess match
- The session leader's role is central to the success of *Brainstorming* sessions. Elaborate.

### B3.

(a) Quality has been defined(ANSI, 1978) as: ..*"the totality of features and characteristics of a product or service that bear on its ability to satisfy given needs"*...

Explain clearly how this definition leads to the three practical aspects:

*Quality of Design/Redesign*

*Quality of Conformance*

*Quality of Performance*

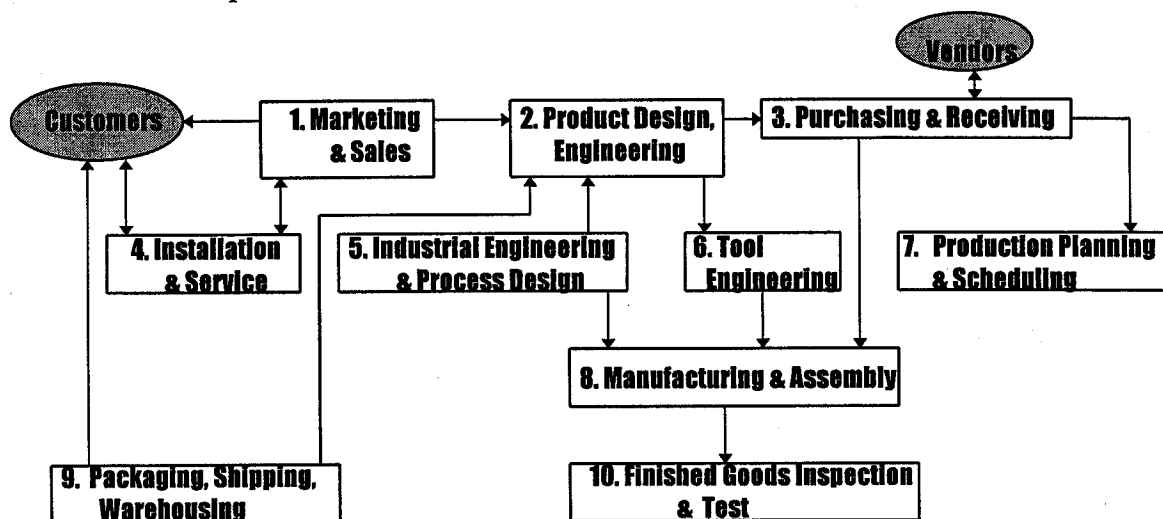
[5 marks]

Consider the following 'process walkthrough diagram'; use it to demonstrate that

...*"Quality is Everyone's Business"*....

by indicating/explaining how it is that each of the ten functions has exposure under at least one of the aspects above.

[11 marks]



(b) Broadly speaking, what type of information should Quality Manuals contain? [4 marks]

Explain how a process walkthrough diagram, such as that presented in (a) above, could be useful when an organisation sets about developing/writing its Quality Manual [5 marks]

### B4.

Provide three separate arguments to support or refute the following claims - at the start of each, indicate whether you intend to support or refute the corresponding claim.

(i) "ISO9000 is about documentation, so it has no implications for product quality"

[9 marks]

(ii) "When selecting vendors, organisations should consider only those which are ISO9000 accredited"

[8 marks]

(iii) "When setting out to achieve ISO9000 accreditation, companies with limited inhouse expertise (in matters related to quality), should recruit a consultant to complete all of the activities involved"

[8 marks]