Unit 300 Advanced engineering analysis

General comments

The syllabus has been extended this year to include a new Section D: Statistical analysis of engineering systems and processes. However, none of the candidates who took the examination answered questions from Section D. Indeed, only questions from Sections A and B were attempted. The average number of questions answered by each candidate was three instead of the four expected.

Comments on individual questions

Question 1

This question concerns the analytic solution of an unsteady two-dimensional temperature distribution in a flat plate by the separation-of-variables method. candidates wrongly ignored the time variable in the separation-of-variables method and instead attempted to develop a steady state solution for the temperature distribution using the x and y variables only and the given boundary conditions. However, even that analysis was incorrect. The candidates then attempted to evaluate the temperature at the centre of the plate as required by part b) using the expression given in part a). However, too few of the required summation terms in the temperature distribution expression were included in the calculation, leading to a poor result. Other candidates correctly used the three independent variables to start the separation-of-variables method but made several errors when the problem had been reduced to a set of ordinary differential equations. Candidates wrongly applied the given boundary and initial conditions to the solutions of the individual ordinary differential equations instead of applying them to the complete composite solution. Also, the solution developed for the ordinary differential equation in the time variable was wrong. The question was not completed.

The numerical answer is:

b) 51.4 ° C

Question 2

No attempt to answer this question.

The numerical answers are:

b) the solution is symmetrical about the centreline *(i=0).*

j	$C_{0,j}$	$C_{1,j}$	$C_{2,j}$	$C_{3,j}$
0	30	30	30	5
1	28.08	26.15	16.54	5
2	23.34	20.53	14.17	5
3	20.41	17.48	12.00	5

Question 3
This question requires the solution of a second order hyperbolic partial differential equation using the method of characteristics. The candidates that attempted this question offered incomplete solutions that were poor and showed little understanding of the method of characteristics. In part a) none of the candidates were able to satisfactorily explain the terms domain of dependence and domain of influence even though these domains have important roles in the method. None of the candidates were able to obtain the characteristics solution in part c).

The analytic answer is:

c)(i) $u(x,t)=\frac{1}{2}F(x+ct)+\frac{1}{2}F(x-ct)$ where *F()* is the given initial displacement function

Question 4
This question features the application of linear programming (LP) to find an optimal solution for the given production problem. All candidates attempted the question and each of them demonstrated a good understanding of the technique and was able to correctly set up an LP model of the problem and develop a sequence of tableaux to obtain a feasible solution which maximised profit. The solutions generated for parts a) and b) of the question were acceptable although in two cases some numerical errors were introduced. The candidates who attempted part c) and presented a completely correct solution for the additional resource allocation.

The numerical answers are:

b)(i) 2, 4 and 8 units/day for fertilizers 1, 2 and 3 respectively
(ii) £220/day
(iii) Unit worth of A, B and C is £4, £1 and £6 respectively
c) Increase chemical A by 2 units/day for an extra profit of £8/day

Question 5
This question is concerned with finding the minimum of a one-dimensional unimodal function by the use of Brent's search method. From the candidates who attempted the question the solutions produced was very poor and incomplete. In part a) the need for a triplet of points to bracket a search region was not answered while the description given of Brent's method was poor and seemed to be based only on the information provided in part b) of the question. No attempt was made to derive the expression given in part b) while in part c), only one iteration was made which contained several numerical errors.

The numerical answers are:

c) $x = 0.96$, $f(x) = 6.1 \times 10^{-3}$

Question 6
This question is concerned with finding the minimum of a multivariable function using a conjugate gradient method as presented in the Fletcher-Reeves algorithm.

The numerical answers are:

b) $x_1 = -2.0 \times 10^{-6}$, $x_2 = 1.0$, $f(x_1, x_2) = -1$

Question 7
No attempt to answer this question.

The analytic answers are:

a)(i) $R_x(\tau)=V^2\left[1-\tau/T\right]$ for $0 \le \tau \le T$

$R_x(\tau)=0$ for $\tau > T$

(ii) $S_x(\omega)=V^2T\left(\frac{\sin \omega T/2}{\omega T/2}\right)^2$

Question 8
No attempt to answer this question.

The analytic answers are:

b)(i) $$S_x(\omega) = \frac{16}{\omega^2 + 16}$$

(ii) $$|H(\omega)| = \frac{\left[(1+5\omega^2)^2 + 16\omega^2\right]^{1/2}}{1+25\omega^2}$$

$$\angle H(\omega) = \tan^{-1}\left(\frac{-4\omega}{1+25\omega^2}\right)$$

(iii) $$S_y(\omega) = \frac{16(1+26\omega^2+25\omega^4)}{16+801\omega^2+10050\omega^4+625\omega^6}$$

Question 9
No attempt to answer this question.

The numerical answers are:

b)(ii)
y(-3) = 0
y(-2) = -9
y(-1) = 0
y(0) = 1
y(1) = -7
y(2) = 1
y(3) = 0
y(4) = -4
y(5) = 0

Question 10
No attempt to answer this question.

The numerical answers are:

b) the plan is

A	*B*	*C*	*D*	*E*	*F*	*G*
1	4	2	8	9	14	11

The plan is Resolution IV

c)(ii) the ANOVA table is

Source	*SS*	*df*	*MS*	*F*
A	6.125	1	6.125	4.111
B	1.445	1	1.445	
AB	6.845	1	6.845	4.594
C	99.405	1	99.405	66.715
AC	7.605	1	7.605	5.104
BC	0.045	1	0.045	
ABC	17.405	1	17.405	11.681
Residual		2	1.49	

only factor C has a significant effect

Question 11
No attempt to answer this question.

The numerical answers are:

c) s_0 = 1.1332 within samples variation
s_1 = 0.3254 random between samples variation
s_t = 1.179

Question 12
No attempt to answer this question.

The numerical answers are:

b) $\sqrt{b_1} = 0.9827$, $b_2 = 3.1107$

c) $\ln \bar{x} = 2.848$, $\ln s = 0.62812$

d) proportion defective is 0.0455
graphical value is 6%

Unit 301 Gas dynamics

General Comments
As in previous years the examination paper covered all aspects of the syllabus. Unfortunately, in May 2006, no-one sat the paper.

Comments on individual questions

Question 1
One-dimensional flow

1b, $$p_0^{\frac{\gamma-1}{\gamma}} = p^{\frac{\gamma-1}{\gamma}} + \left(\frac{\gamma-1}{\gamma}\right)\left(\frac{\rho}{p^{\frac{1}{\gamma}}}\right)\left(\frac{u^2}{2}\right)$$

1c, $$p_0 = 1.959x10^5\,N/m^2, T_0 = 420.8K$$

Question 2
Pitot-static tube and normal shock

ai, $$M = 0.289, (p_0 - p) = 5.97x10^3\,N/m^2$$

aii. $$M = 0.867, (p_0 - p) = 6.33x10^4\,N/m^2$$

aiii, $$M_1 = 1.445, (p_{02} - p_2) = 9.41x10^4\,N/m^2$$

b, $$s_2 - s_1 = 17.16J/kgK$$

Question 3
Normal shock

Question 4
Isentropic flow in a converging-diverging nozzle

c, $$A_t = 932.9mm^2, m_{max} = 0.2195kg/s$$

Question 5
Compressible flow with heat addition

ai, $$T_{02} = 935.9K, T_2 = 795.8K, p_{02} = 1.323bar,$$
$$\rho_2 = 0.328kg/m^3, u_2 = 530.5m/s, M_2 = 0.938$$

Question 6
Compressible flow with friction

a, $L_{13} = 1.483\text{m}$

b, $M_2 = 0.674$

c, $L_{12} = 1.338\text{m}$

Question 7
Compressible flow with heat addition

$$M_2 = 0.583, T_2 = 1206.2\text{K}, p_2 = 0.717\text{atm}, \rho_2 = 0.21\text{kg}/\text{m}^3$$
$$T_{02} = 1287.9\text{K}, p_{02} = 0.903\text{atm}$$

Question 8
Shock-boundary layer interactions in supersonic flow

Unit 302 Computational mechanics using finite element method

General comments

This was the fourth year of this examination. The paper follows a standard format of a theoretical Section A and Section B consisting of numerical problems.

Comments on individual questions

Section A

Question 1

Brief (three well-phrased sentences) descriptions of key terms expected. Element stiffness discussion requires a more lengthy description with summary matrix-type equations.

Question 2

The yield surfaces, a cylinder and a cone, respectively, should be drawn in principal stress space.

Fuller discussions with suitable examples of a contact element analysis are sufficient. A diagram of the FE analysis is useful, with any frictional stresses indicated.

Question 3

Discussions should be brief and any diagrams should be suitably labelled. The isoparametric element should be drawn twice with both parent and local coordinate systems indicated.

Section B

Question 4

This is a classic problem involving the ‘ F = k · d ‘ system of equations for the 6-dof simple beam element system. Once the element stiffness matrices have been evaluated, these must be then assembled to form the system stiffness matrix. The system reduces to a 3×3 system on application of boundary conditions, which then requires rigorous solution for the deflections, slopes, reaction forces and moments.

Question 5

This question guides the student through to deriving the element stiffness matrix for a 3-node *constant strain triangle* element. Differentiation of the shape functions provides the element strain-displacement matrix and matrix multiplication provides the element stress vector.

Question 6

This problem requires an understanding of how FE deals with distributed and centrally-located concentrated loads acting over beam sections in order to obtain resultant equivalent nodal forces and moments. Part (b) requires the evaluation of nodal force components from the stresses and areas that are provided.

Unit 303 Telecommunications engineering

General comments

This was the fourth year of presentation of this examination. Unfortunately, once again, no candidates entered for, and therefore sat, the examination. So it is not possible to comment on their performance in individual questions. The syllabus for this subject and its introductory counterpart are now rewritten to complement one another in a progressive way. This may lead to students taking the paper in future years. The following comments may be made on the individual questions.

Comments on individual questions

Question 1

This question is concerned with the cell structure in cellular communication systems. The first part asks for an explanation of the structure and its enabling features. The second part tests the historical perspective of students of the evolution of mobile telephony. So that in the future they will be able to predict possible paths of development. The third part tests their ability to apply their knowledge by way of a small calculation.

Question 2

The aim of this question is to test students' understanding of the concepts of multiplexing. Following an introductory part, the question focuses on CDMA, its generation and reception, attributes and advantages. The question also asks for the derivation of the number of users of a cell in terms of its relevant parameters.

Question 3

This question is concerned with the transmission between local exchanges and the subscribers' premises, the so called 'last mile home'. It deals with the current infrastructure, the current ADSL technology for Broadband and with currently envisaged possible technologies for the future.

Question 4

This question is designed to test students' understanding of statistical decision processes in digital communication. A bare pass may be obtained from the initial, descriptive part of the question, but for higher marks candidates are required to complete two calculations.

Question 5

Following a descriptive part demonstrating their understanding of the geometry of the orbits of geosynchronous satellites this question requires candidates to perform a series of calculations of three parameters of the uplink of a satellite transmission system.

Question 6

This question tests candidates' understanding of local area networks (LANs). A bare pass (40% of the marks) is allocated to the descriptive, first part. This requires a broad understanding of the basic principles of the techniques employed in three different LAN implementations. The calculation is arithmetically simple but it requires a good grasp of the underlying principles.

Question 7

This question is designed to test candidates' knowledge of the fundamentals of light propagation in optical fibres. As in previous question a bare pass (40% of the marks) is allocated to the descriptive, first part. The remaining 60% of the marks are allocated to part c) which requires the calculation of the maximum link length and data rate in a given system. Once again, the calculations are arithmetically simple, but require a good understanding of the underlying principles.

Question 8
This question tests the understanding of the principles of packet switching. Once again a descriptive part, sufficient for a bare pass, is followed by a calculation which demonstrates ability to apply knowledge of the principles of packet switching.

Question 9
The purpose of this question is to test candidates' knowledge and understanding of some of the modulation schemes used in data modems and GSM digital communication links. A bare pass may be obtained by the correct answer to the calculation in the last part of the question. Candidates must be able to provide the appropriate relationships and know how to use these.

Unit 304 Advanced manufacturing

General comments
This was the third year for this module and this time no candidates sat the examination. This paper was set to cover the syllabus for the subject and the following comments may be made on the individual questions. Every question carried equal marks.

Comments on individual questions

Question 1
This question is designed to test students' understanding on the integrated nature of design and manufacture with all cost implications and the effect of various stages of manufacture on the others. The answer had to include the graphical representation the opportunity for and the difficulty of each stage of the cost distribution in manufacturing. Marks were allocated to the graphs and the discussion elements.

Question 2
The aim of this question is to test students' knowledge on the effect of parts quality on assembly systems performance indicators. This question is of numerical type to establish performance indicators of an actual assembly system if the quality parameters of the component parts are known. The describing equations were provided.

Question 3
This question tested the students' understanding on machining systems' limitations and process parameter optimisation. The constraints included the machined part's rigidity and power supply limit in an attempt to set the most productive cutting speed and utilise machine tool. In this numerical question some equations were provided to find the answers.

Question 4
This question tested the students' understanding on High-Speed-Machining (HSM) focussing on system approach followed in the development of HSM. The answer required a suitable block diagram with each steps indicated. Also, the advantages of HSM had to be listed, explained and commented. Both development and advantages phase carried equal marks in the graphical/ reasoning question.

Question 5
This question required sound knowledge on laser beam applications in laser cutting, where a suitable diagram was supplied to chose process parameters for given conditions. The combination of graphical and numerical information tested the students' ability to apply obtained knowledge in laser cutting.

Question 6
This question requires a reverse engineering solution to be presented from data capture to physical object stage supported by a suitable block diagram and sufficient reasoning. This graphical/ reasoning question tests the students' knowledge on CAD/CAM strategies in reverse engineering. Part of this question was concerned with setting up process parameters for Rapid Modelling.

Question 7
This question is set to check the students' knowledge on Statistical Process Control (SPC) in manufacturing. This numerical question sets a real industrial problem to solve with measured dimensional values of a component part and also provides mathematical equations for the solution. The question has Part (a) and Part (b) of equal mark allocation.

Question 8
This question targets the environmental/ tribology issues of advanced manufacturing. A suitable block diagram has to be presented and discussed for the minimum amount of cutting fluid application and its advantages must be analysed. This graphical/ reasoning question also covers the advantages of this technology over the traditional flood-type cutting fluid application.

Unit 305 High performance computer systems engineering

A report has not been published for this subject.