INTRODUCTION

The reports contained in this booklet are designed to be informative and helpful both to candidates and those responsible for preparing them. The Examinations Committee will be pleased to receive any comments or constructive criticism on the content of the reports, either of a general nature or relating to a particular subject. The Committee emphasises that the individual subject reports should be read in conjunction with the appropriate question papers. These are available from the Engineering Council Examinations department at City & Guilds in sets for Part 1/Certificate examinations and individually for Part 2/Graduate Diploma examinations.

MAY 2003 – PART1/CERTIFICATE EXAMINATION

ANALYSIS OF RESULTS BY SUBJECT

Subject	Number of Candidates	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Average Mark	%Pass Rate
PART 1/ CERTIFICATE UK									
C101	2						2	19.5	0.0
C102	1		1						100.0
C103	1						1		0.0
C104	Nil								
C105	1				1				100.0
C106	Nil								
C107	1						1		0.0
C108	Nil								
O'SEAS									
C101	347	6	24	67	108	14	128	37.9	59.1
C102	295	12	36	81	67	17	82	43.5	66.4
C103	300	1	11	46	75	20	147	33.6	44.3
C104	246	1	20	67	92	22	44	43.6	73.2
C105	234	9	17	44	79	12	73	41.4	63.7
C106	140	1	5	10	40	5	79	32.4	40.0
C107	198	2	13	46	64	6	67	38.6	63.1
C108	50				7	1	42	20.1	14.0

SUBJECT – C101 MATHEMATICS

General Comments:

This year the format and structure of the paper were changed. The number of questions was reduced from 13 to 10, allowing more in-depth questions on the topics examined. The number of topics examined was reduced in commensuration and some ‘favourite’ topics were not examined, for example Maclaurin’s series and vectors. There were very few ‘first class’ performances and this may reflect on candidates banking on topics to occur year in and year out. As always there were many examples of poorly-understood material and lack of basic knowledge. Candidates should be prepared to show ‘engineering common sense’ in relation to their answers, even on a Mathematics paper. More candidates than usual failed to enter the questions attempted on the front cover of their answer books.

Comments on Individual Questions:

Q1
The response to this question, based as it was on fundamental calculus techniques, was disappointing. On the whole, candidates’ answers could be described as poor.
Part (a) was almost universally attempted via the D operator rather than using the auxiliary to find the complementary function and a trial function to determine a particular integral. The former of these tasks required the factorisation of a simple quadratic equation and this caused problems for many.

Part (b) required the conversion of the particular integral into the form $R\cos(2t-\phi)$ and this defeated virtually everyone. It appeared to be the case that many candidates had no idea how to begin the task. Those who were able to find R were universally unable to find ϕ, with the negative coefficient proving the major obstacle. Some were prepared to accept a negative value for R as correct.

Most candidates shied away from Part (c); of the handful of candidates who did attempt this Part most found correctly that $b^2 < 4c$ for an oscillation but no one stated the condition $b < 0$ for damping.

Q2
Part (a) Apart from the occasional error in the sign $\frac{dy}{dx}$ was usually obtained correctly. However, the request to obtain $\frac{d^2y}{dx^2}$ (in the attempted determination of which there were sign errors a-plenty) allowed candidates to demonstrate more fundamental errors: many believed that $\frac{d^2y}{dx^2} = \frac{d^2y}{dt^2} \div \frac{d^2x}{dt^2}$. Much the same number found effectively $\frac{d}{dt}\left(\frac{dy}{dx}\right)$ rather than $\frac{d^2y}{dx^2}$.

Part (b) A significant number of candidates, having shown successfully that $f(0)=0=f'(0)$ and $g(0)=0=g'(0)$, then did not know how to proceed. It may be that, previously, they had never needed to use L'Hopital's rule twice in succession.

Part (c) Some candidates appeared to misunderstand the wording of the question and assumed that $y=f(x)$ referred to the function $f(x)$ in Part (b). Many attempts to find formulae for $\frac{dy}{dx}$ and $\frac{d^2y}{dx^2}$ were successful – even ρ was obtained correctly on occasion – but candidates did not then substitute in order to find the value of the radius of curvature at the origin. It was not always realised that the radius is a positive quantity. Few spotted that the curve is a circle and that the radius could most easily be found by the method of completing the square.

Q3
The majority of attempts at this question were successful. It would seem that this is a topic well taught and mastered by students. The partial differentiations were not particularly difficult, but the succinctness of many of the successful attempts suggested a good understanding of the basic principles.

Q4
Part (a) The repeated factor in the denominator of the given rational function caused a considerable number of problems. A range of incorrect partial fractions was tried, including $\frac{A}{x+1}+\frac{B}{x+1}+\frac{C}{x+2}$, $\frac{Ax+B}{(x+1)^2}+\frac{C}{x+1}+\frac{D}{x+2}$, $\frac{A}{(x+1)^2}+\frac{B}{x+2}$. Those candidates who opted for the form $\frac{Ax+B}{(x+1)^2}+\frac{C}{x+2}$ had problems in integrating the resulting fraction $-\frac{x}{(x+1)^2}$. Rather too often the integral $\int \frac{1}{(x+1)^2}\,dx$ was thought to be a multiple of $\frac{1}{(x+1)^3}$.
Even when the indefinite integral had been found correctly its evaluation at the limits of the definite integral caused a number of thus far successful candidates to falter.

Part (b) Many candidates opted not to derive the trigonometric identity $\cos 4\theta \equiv 1-8\cos^2\theta\sin^2\theta$ but merely used it to evaluate the definite integral, in most cases successfully.

Q5
As always, the Fourier series question caused many problems and there were very few completely correct answers. Some candidates were unaware that they were dealing with an even function and therefore of the consequences for evaluating the Fourier coefficients. Others were confused between the consequences for an even function and for an odd function. This year many candidates took what they considered to be a soft option and ignored the modulus sign in the definition of the function. Some who had written down correctly the formulae for evaluating the Fourier coefficients then ignored the modulus signs when working out the integrals. The happy relatively few who formulated the necessary integral for the determination of the coefficients of the cosine

terms ran into trouble trying to use the method of integration by parts. Often the (correct) appearance of the expression $1-\cos n\pi$ was not accompanied by its correct evaluation.

Q6

Part (a) This part was surprisingly badly attacked. Only a few of the candidates even attempted to use de Moivre's theorem and most of those did not really understand what they were about. The simple expedient of obtaining one of the roots by taking the cube root of the modulus of the given number and dividing its argument by three, then obtaining the two other roots by adding 120 degrees to the argument was not in the repertoire. A popular approach was to put $z = x + yi$, then write out z^3 and put the result equal to 27*i*. Unfortunately, this leads to a pair of equations which are difficult to solve.

Part (b) This part was handled considerably better than Part (a). Nonetheless, many candidates wrote the transformation down incorrectly as $w = \dfrac{z+i}{2z-i}$ or $w = \dfrac{z+1}{2z-1}$. Some thought that the complex conjugate of $2z-1$ was $2z+1$. Then there was a fair dusting of algebraic errors; otherwise candidates were clear on how to proceed.

Q7

This question supplied most candidates with a significant number of marks, especially those who performed poorly overall. The allocation of 6 marks for Part (a) was in hindsight overgenerous. There is little to be said about Part (a) other than that the vast majority of candidates answered it correctly.

Part (b) On the whole this was answered correctly, almost invariably by the use of the adjoint matrix as a step to finding the inverse, although some attempts did not include the transposition of the cofactor matrix. Significantly many candidates were under the impression that they had to prove the matrix relationship $\mathbf{L}^{-1}\mathbf{U}^{-1} = \mathbf{A}^{-1}$ and, having found $\mathbf{L}^{-1}$ and $\mathbf{U}^{-1}$, went on to find $\mathbf{A}^{-1} = \dfrac{adj(\mathbf{A})}{|\mathbf{A}|}$ in addition to the product $\mathbf{L}^{-1}\mathbf{U}^{-1}$.

Q8

Part (a) was badly answered. Some candidates opted for the Poisson distribution rather than the binomial distribution. Those who chose the correct distribution were mostly able to answer the question correctly but the wording may well have confused some candidates, who found $1-\{P(X=0)+P(X=1)\}$ where X is the number of faulty components.

Part (b) was answered correctly by almost no one. Those candidates who had successfully completed Part (a) failed to realise that they needed to change the random variable being considered.

Q9
Only a few candidates grasped the notion of working backwards from the table of the normal distribution in order to find the mean and standard deviation. Several candidates had not appreciated that the deviation from the mean had to be negative for the lower tolerance. As a result, some bizarre values were proffered, including negative values for the standard deviation. Do people not ask themselves whether the answer they put forward is reasonable? The concept of the expected cost *per usable bolt* was beyond virtually everyone. This must be deemed a hard question.

Q10
In almost all cases this question was either not attempted or answered correctly up to the point of declaring the composite statements logically equivalent. To show that they could be more simply expressed as B was meant to be easy – simply glancing across the truth table(s); how optimistic! Far too much effort went into elaborate attempts which got nowhere.

SUBJECT C102 – ENGINEERING MATERIALS

Comments on Individual Questions:

Q1
This question was not done well by many candidates. The answers to the first part were incomplete with very few candidates discussing the repeating unit cell and long range order seen in crystalline materials vs. the disordered state seen in amorphous materials. Virtually all candidates described semi-crystalline as a single phase somewhere between crystalline and amorphous, as opposed to a two phase mixture of crystalline and amorphous regions. The second part, was again poorly answered with many students writing long essays on the atomic structure of metals, but omitting to answer that metals were typically crystalline. The inclusion of the word "alloys" led many candidates to discuss two phase mixtures which was not necessary for this question. The final part did not yield many marks for the majority of students. Only a handful of candidates appeared to understand the question, and discuss the structure in terms of regularity and size of side groups, and the specific processing conditions, such as cooling rate, that would give rise to a certain degree of crystallinity.

Q2
A fairly straightforward question, with many candidates scoring high marks. Determination of yield stress, ultimate tensile stress and Young's modulus were done well by most candidates. A few candidates lost marks for incorrect units, but otherwise these parts were well understood. Part (c) caused most problems with few candidates understanding the concept of proof stress, or the value of strain to use to calculate the proof stress. Many candidates assumed 1% proof stress corresponded to 0.1mm extension and hence calculated a value of proof stress much too low. Part (e) also caused a few difficulties and resulted in many candidates giving the wrong units for the answer - an answer in Joules was expected, but answers in J m^{-3} were accepted provided they were numerically correct.

Q3
By far the most badly answered question. A new style of question and it was obvious that candidates were unprepared for this subject matter. All parts were poorly answered. Common problems / misconceptions included:

The first part of the question asked for 'electronic arrangement" - this was ignored and candidates simply wrote about mechanical properties. For a few candidates, "transition metals" was interpreted as "transistor metals" and a discussion on semiconductors and doping followed.

Allotropes were assumed to be the opposite of isotopes, i.e. the same number of neutrons but different number of protons. The word "allotrope" was simply not understood - a few candidates mentioned graphite and diamond as different forms of carbon, but did not appreciate that this was what is meant by the word allotrope.

Q4
An old favourite for which candidates were well prepared and scored highly. Lots of candidates drew excellent phase diagrams with the only common flaw being the position of the eutectic point at 85 wt% Al. The composition axis was often reversed with candidates drawing in the eutectic nearer the Si end of the diagram. Most candidates identified the eutectic composition as most suitable for casting although not all of them explained why - low melting point etc. Part (c), the lever rule calculation, was the only tricky part for most candidates with less than half the candidates getting the correct answer. Some of the calculations were very long winded for what is a relatively simple two line calculation. The drawing of the lamellar microstructure did not trouble many candidates.

Q5
This question on the electronic structure of semiconductors and simple circuits was done very well and shows that candidates are well prepared in this area of the syllabus. Nearly every candidate explained how doping worked, although one or two mixed up the terminology of n-type and p-type. On the whole, the circuits drawn for rectifiers and transistors were very good and the accompanying descriptions of their biasing, doping level, and mode of operation were equally good. The only part that was not well explained was why electrons (or holes) flow from the emitter straight through the base to the collector without recombining with holes (or electrons) in the base. The final part of the question was straightforward and most candidates were able to achieve good marks with their description of appropriate dopants and the recombination of electrons and holes to produce a photon of light in the visible spectrum.

Q6
This question was not very discriminatory with virtually all candidates getting approximately half marks. A broad range of answers was accepted as correct. The question did reveal a number of misconceptions of candidates and a confusion between common engineering terms such as toughness, strength and stiffness, but otherwise it was a straightforward question.

SUBJECT C103 – ENGINEERING SCIENCE

General Comments:

The syllabus covers areas of Mechanics, Thermodynamics, Fluid Mechanics and Electrical Engineering. Overall the performance in each of these areas was similar, although it appeared that candidates from some centres had not covered some aspects of the syllabus.

Comments on Individual Questions:

Q1
Most candidates were familiar with the stress-strain relationships involving Poisson's ratio. Many were therefore able to determine the two components of stress. A smaller number of candidates were able to use Mohr's circle to obtain the shear and axial stresses of 64.6 MN/m^2 and 0 MN/m^2 respectively required for part (i) of the question. The majority of candidates correctly wrote down the relationship between the torque in the shaft and the shear stress at its surface. The correct value of 4363 Nm for the torque required in part (ii) was obtained by relatively few candidates though because of failure to complete part (i) correctly or because of numerical errors in part (ii).

Q2
Most candidates tackled part (a) of this question by considering the complete bridge structure and obtaining two equations by resolving the forces in a vertical direction and taking moments about either A or B. Generally these candidates were successful in obtained the two reaction forces of 1.074 kN and 0.926 kN through the combination of these two equations. Incorrect answers resulted from errors in determining the relevant geometrical lengths or numerical errors. Candidates should be encouraged to estimate the reaction forces in problems of this type. From Fig. Q2 it is clear that the reaction forces at the two ends are going to be approximately equal and if some candidates had made this simple estimate they would have realised that the answers which they had obtained through their calculations were in error.

A significant number of candidates did not appear to know how to draw free-body diagrams. As stated in the question a diagram should have been drawn for each of the three components of the bridge separately. Many candidates did not recognise that if friction can be neglected the reaction forces at A and B and the additional forces acting between the component parts of the bridge will all act in the vertical direction. The incorrect inclusion of horizontal components to these forces did not prevent however candidates from obtaining the correct magnitudes for the vertical components. Some candidates did not recognise that there are two reaction points between each of the component parts of the bridge and hence omitted some of the forces from their diagrams and calculations. The four reaction forces between the component parts of the bridge have magnitudes from left to right of 3.882 kN, -2.807 kN, -2.420 kN and 3.346 kN.

Q3
Many candidates were successful in obtaining the algebraic expression required in this question. Almost all candidates tackled the question by considering the forces acting on the various components and hence determining the expression for the acceleration through Newton's second law. An alternative approach, which is perhaps simpler, is to equate the changes in potential and kinetic energy of the system and then to

differentiate the resultant expression with respect to the distance moved by the truck in order to obtain its acceleration. The most frequent errors in the solution of the problem were neglecting component parts of the system, most commonly the inertia of the wheels, or use of the wrong direction for one or more of the inertia forces.

Q4

Q4 posed some conceptual difficulties for many candidates. Most were able to sketch some form of graph for the wheel peripheral velocity and aircraft velocity and recognised that when these became equal the wheels cease to slip. Many candidates did not recognise though that when the aircraft lands and the wheels accelerate this will result in a deceleration of the aircraft even though there are no horizontal forces acting on the aircraft as a whole. Many candidates also did not deduce that the acceleration of the wheels will be proportional to time if the weight of the aircraft acting on the wheel is constant.

The majority of candidates were able to derive some form of equation for the horizontal reaction force between each wheel and the aircraft. This did not always result in the determination of the correct time for the cessation of slipping of 1.23 s though. This was due either to an incorrect equation or numerical error.

The determination of the aircraft velocity was simply determined from the deceleration force and time determined earlier in the question. Generally the correct value of 40.32 m/s was obtained where candidates had obtained correct answers to the earlier parts of the question. Many of the remaining candidates were nevertheless able to demonstrate a correct approach to solve this part of the question.

Q5

Most candidates demonstrated the ability to tackle this type of question and many of these were able to obtain the correct values of V_{OB}=4.125v V_{OC}=7.060v V_{OE}=3.325v, i_B = 4.034μA and i_E=1.01 mA. Errors generally resulted from numerical mistakes rather than in method. Some candidates returned answers which were clearly in error. In particular voltage values that exceeded the supply voltage of 12 v and currents that were 1000 times too large. Candidates should be encouraged to consider whether their answers are realistic.

A significant number of candidates were unable to draw a correct small signal equivalent circuit. Most were however able to determine the small signal voltage gain although a significant number were unable to convert this into dB. The correct answer was 45.8 dB.

Q6

The majority of candidates were able to derive the standard expression for the work done in compressing a gas adiabatically in terms of the initial and final volumes. However, many of these candidates had difficulty in determining the volumes in terms of the distances x and x_0 in the question.

Most candidates recognised that the answer of 0.98 in required for part (b) could simply be obtained by substitution of the relevant quantities into the equation derived in part (a). A number of candidates were unable however to correctly deduce that the work done by the damper was equal to the kinetic energy of the lift immediately prior to impact.

Relatively few candidates attempted part (c) of the question. In order to do this part it needs to be recognised that when the lift has been brought to rest the force resulting from the compressed gas will exceed the weight of the lift and so the lift will move upwards until equilibrium is established where the damper force equals the weight of the lift. The position of the damper can be determined from the required pressure for equilibrium through the relationship pV^{γ} =constant given in the question, giving the final equilibrium value as x = 0.0647m.

Q7
Candidates used a variety of techniques in order to determine the algebraic expression required for part (a) of this question. The direct approach of writing down an integral expression for the torque on the gate was the quickest and most successful. Some candidates chose to determine the force acting on the gate and then to determine the point at which this force acted. This led to a significant amount of unnecessary algebra. Other candidates used standard results for the force and point of action for immersed rectangular surfaces. This approach was frequently successful but nevertheless involved more algebra than for the direct approach.

The majority of candidates recognised that the gate would open when the torque derived in part (a) of the question dropped to zero. Most attempts at this part of the question therefore resulted in the correct answer of 1.83m.

Q8
Almost all candidates attempted this question by one of two methods. The majority derived three equations for the three loop currents and then determined the three voltages from the currents. This method was successful, but frequently numerical errors led to incorrect values for the loop currents and hence for the voltages. The second and superior method, was to consider the three node voltages as the unknowns and to derive three equations equating the currents at the nodes A, B and C. This method involved less algebra and hence was more frequently successful in rendering the correct values of 3.90v, 3.17v and -1.83v for the node voltages A, B and C respectively. Candidates should be encouraged to make approximate estimates for the voltages in this type of question and to compare their answers with these estimates. Such an approach would have enabled many candidates to recognise that their answers were in error.

SUBJECT C104 – ENGINEERING PERSPECTIVES AND SKILLS

General Comments:

This syllabus covers a wide area of engineering, and consequently the variety of questions on this paper was specifically designed to reflect this. This year there seems to have been a better attempt at most of the questions on the paper and also less time and effort was wasted simply writing about a subject “near “ to that requested.
However, there was a heavy dependence on answers to Q3 and Q4.

Comments on Individual Questions:

Q1

(a) Some of the typical points that could be made are listed in the Engineering Council publication which includes a

10 POINT CODE OF PROFESSIONAL PRACTICE ON RISK ISSUES

1. PROFESSIONAL RESPONSIBILITY	Exercise reasonable professional skill and care
2. LAW	Know about and comply with the lass
3. CONDUCT	Act in accordance with the codes of conduct
4. APPROACH	Take a systematic approach to risk issues
5. JUDGEMENT	Use professional judgement and experience
6. COMMUNICATION	Communicate within your organisation
7. MANAGEMENT	Contribute effectively to corporate risk management
8. EVALUATION	Assess the risk implications of alternatives
9. PROFESSIONAL DEVELOPMENT	Keep up to date by seeking education and training
10. PUBLIC AWARENESS	Encourage public understanding of risk issues

A significant number of candidates had clearly studied the IEE publication, although many ignored the instruction to "list" the main rules in a form similar to the above.

(b) The role of models in engineering design. A typical model classification is

Descriptive versus Predictive
Deterministic versus Probabilistic
Iconic (physical) versus Analogue versus Symbolic (mathematical equations) versus
Numerical (simulation)
Iconic can be further expressed as
Proof of concept models
Scale models
Experimental models
Prototype models

Answers to this section were often very garbled and not described in a systematic way such as the above.

(c) The three major financial statements are
(1) Balance sheet (2) Profit and Loss account (3) Funds Flow statement

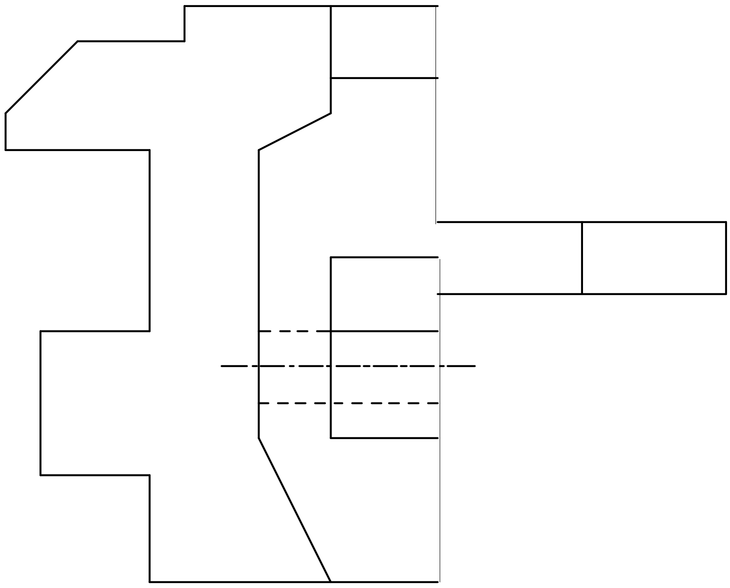
When attempted, the answers to this section were often satisfactory

Q2

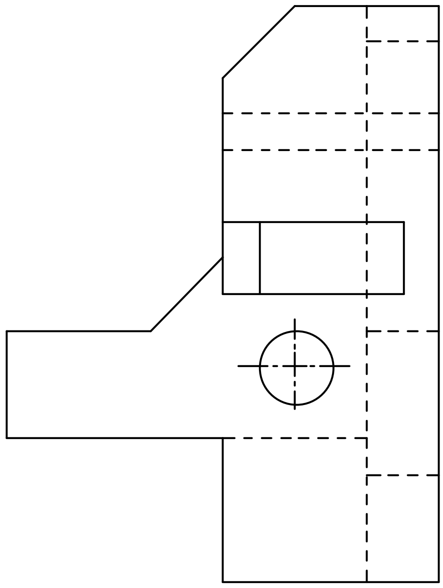
The most appropriate missing words are identified as follows

1 oblique or cabinet projection	2 life cycle cost	3 closed-loop
4 validate	5 activities	6 flash
7 processor or CPU	8 multiprocessing	9 compiler
10 module		

Q3
(at the end of a specific period) (third angle)



VIEW A



VIEW F

Incomplete views and missing hidden details were common problems, particularly in view F.
Sometimes candidates produced views other than those requested (A& F), particularly view C instead of view F.
The best responses used the standard graph paper in the centre of the answer booklet to produce good, scale drawings, but often the views were drawn directly into the answer book, with consequent distortions of scale.

Q4
This is a straightforward network problem, which is very similar to that given in the list of specimen questions published previously.
The critical path is = 1 -- 3 -- 5 -- 7 -- 9 and the expected project completion time
m = 60+30+70+90 = 250days
Project variance = 100 + 11.11 + 177.77 + 400 = 688.88
project SD $\sigma = \sqrt{688.88} = 26.2465$

Probability that project is completed in less than 230 days
$Z = (x - \mu) / \sigma = (230-250) / 26.2465 = {}^{-}0.76$ and from standard normal table, ignoring the negative,
prob. = 0.2764, so % probability = {1 - (0.5 + 0.2764)} 100% = 22.36 %

Some candidates did not use the three time estimates correctly, which requires the following: -

expected time = (a +4m + b)/6 and variance = $[(b-a)/6]^2$

Q5

(a) By its nature the answer to this question is specific to each individual examination candidate.
Ideally, a flowchart, pseudocode, or other <u>planning</u> device should be clearly stated and then used, before completing the coding task required by this specific problem.

When attempted, the answers were often satisfactory, although some candidates did not identify clearly the method or language adopted.

(b) Rearranging equation (3), the required solution is when y = 0

$$y = \sqrt{(s^2 + 3t^2)} - \frac{Y}{n}$$

The secant method is an efficient approach which, after only three iterations yields the 'best' value of the root
P = 51000 N, M = 300 Nm, T = 600 Nm, Y = 600 MN/m², n = 4 and D is between 30 and 40 mm.
In general, the revised value of the root is given by the following expression

$$R = a + \frac{y_a}{(y_a - y_b)}(b - a)$$

Iteration	D	s/10^8	t/10^8	y/10^8	R revised value of root
	a=0.030	1.85327	1.13177	ya=1.19765	
1	b=0.031	1.70144	1.02574	yb=0.95994	0.035038
	a=0.035	1.24280	0.71272	ya=0.25167	
2	b=0.036	1.15600	0.65496	yb=0.11965	0.036906
	a=0.0369	1.08509	0.60819	ya=0.01232	
3	b=0.0379	1.01338	0.56131	yb=-0.09567	0.037014

ie the estimated value of the minimum necessary diameter D = 37.01 mm

Even though the question clearly requested a systematic and numerical approach (as indicated by the appropriate method to be used), a significant proportion of candidates ignored this, and wasted time trying to find an analytical solution. Very few candidates obtained the correct numerical values; often errors were made due to the inability to handle the small values involved. Dividing by 10^8 as in the above table obviously makes this problem easier.

Q6
Those items appearing on the balance sheet are numbered 6 to 21 inclusively
The value of the current assets for the year ending December 31, 2002, is the sum of items 6, 11,12,13,14
i.e. £ [37800 +130200 +25200 - 4400 + 10800] = £ 199600

A full balance sheet was not required, but many candidates wasted time by attempting to produce this.

SUBJECT C105 – MECHANICAL AND STRUCTURAL ENGINEERING

General Comments:

This year's paper was very similar in format and structure to last year's and contained seven questions that fully covered the syllabus. Candidate numbers were significantly lower than last year with a reduction of about 40% on the 2002 figure. There was a marked improvement in overall performance with a pass rate of 63% that could be almost wholly explained by the greatly reduced number of candidates that were totally unprepared for the Examination. It would be pleasing to think that this outcome was attributable to students having applied a rational self-assessment procedure in determining their suitability for presentation at the Examination – advise which has been repeatedly given over the past few years. There is still evidence that many candidates show a serious lack of understanding of basic principles and tutors need to address this. Peculiarly with this paper, and despite the clearly written request to do so on the script cover, over 60% of candidates failed to insert the number of the questions they attempted in the boxes provided on the cover sheet.

Individual candidate performance varied hugely from a minimum mark of 2% to a maximum mark of 83%. The overall pass rate was 63.4% compared to 42% for 2002
I believe that the exam paper fairly tested knowledge and understanding of the syllabus. Candidates again tended to favour the questions on statics rather than those on dynamics with the question on the velocity and acceleration of a linkage being particularly poorly done.

This year only 7.7% of the candidates achieved a mark less than 20% which was a significant improvement over recent years (eg 18.9% in 2002 and 25% in 2001). As stated above, it is hoped that this is due in part to better attention being given to self-assessment and preparation.

There were still some serious examples of candidates showing poor exam strategy and time management, and tutors should note that candidates still require some advice and guidance on these aspects

Comments on Individual Questions:

The following comments relate to the particular features and concepts that each question attempts to highlight. In many instances, the numerical answers are of little consequence and credit is given when there is a clear indication that the fundamental principles are understood. Tutors and prospective candidates should take particular note of these comments as they indicate the level of knowledge and understanding expected of each topic at this stage.

Q1

Most candidates recognised this as a statically **indeterminate problem in torsion** although a number, for some inexplicable reason, treated the loading as tension for which they received no credit! Since the solid steel bar and the (hollow) alloy tube are firmly attached to each other, they will experience the same angle of twist when a torque is applied. Since the torque carried by the steel bar is to be equal to the torque carried by the alloy tube it follows from the simple torsion formula that (GJ) for the bar and tube are equal. Hence the (unknown) outer diameter of the tube requires to be 110mm. If a torque of 20 kNm is applied to the composite shaft, each element carries 10 kNm which results in maximum shear stresses in the steel and alloy of 99.5 and 51.6 N/mm² respectively

Q2

Assesses understanding of **equilibrium and free-body diagrams** for a simple pinned frame and was generally well done. For this problem horizontal forces, vertical forces and moments must be in equilibrium. Since there are no external horizontal forces applied to the frame, the reactions at D and F are wholly vertical and equal to 10 kN each. It follows that the force in member DE must be zero, and that in member AD is 10 kN (comp). From the free-body diagram for point A, the force in member AB is 10 kN (tens) and that in member AE is $10\sqrt{3}$ kN (tens). Only now can the forces at point E be resolved. The force in each of the members BE and EF is then 10 kN (tens). Note that since there is no external force applied to the frame at point C, the force in members BC and CF must be zero. On that basis, the force in members BF and EF could be found prior to resolving the forces at point E

Q3

Assesses the concepts of **energy and momentum**. For part (a), most candidates were able to define *kinetic* and *potential energy, momentum* and *impulse.* Part (b) was less well understood. It can be reasonably assumed that when the bullet has come to rest in the block of wood, the resultant kinetic energy of the combined masses will be converted into potential energy at the top of the swing. This gives a velocity of the combined (block + bullet) of 0.82 m/s. Then, if the momentum of the bullet immediately before it strikes the block (ie its effective muzzle velocity) is equated to the momentum of the combined masses at the above velocity, the muzzle velocity of the bullet is found to be 908 m/s

Q4

Assesses the fundamental concepts of **stress at a point** in a shaft subject to **axial torsion and thrust** (ie axial compression). Candidates showed a much improved understanding of the concept of stress at a point as illustrated using the Mohr circle technique which is not only the simplest method of analysis but also clearly demonstrates levels of understanding. In this example, the axial compressive stress due to the thrust alone is 71.3 N/mm². The torque applied to the shaft in transmitting 800 kW of power at 120 rev/min is 63660 Nm. So the resulting maximum shear stress in the shaft due to the torque acting alone, from the simple torsion formula, is 119.7 N/mm². The principal stresses due to the combined loading of thrust and torque are then 89.2 N/mm² (tens) and 160.6 N/mm² (comp).

It is important that the nature of these stresses, ie tens or comp, is clearly shown. The maximum shear stress due to the combined loading is 125 N/mm² (ie the radius of the Mohr circle in those terms)

Q5

Assesses understanding of **shear force and bending moment distributions**, along with applications of the **simple bending formula**, for a statically determinate beam problem. Most candidates demonstrated good understanding of shear force and bending moment diagrams and the relationships between them. The reactions at B and D are 26.7 kN and 8.3 kN respectively. It should be noted, however, that the mathematical 'maximum' bending moment that occurs between points C and D (and equals 3.44 kNm) is not, in fact, the maximum numerical bending moment on the beam. This occurs at the support point B and is equal to 15 kNm in value. Consequently the maximum bending stress in the beam cross-section is 156 N/mm² at section B

Q6

This question required the assessment of the **SHM of a spring-mass system** and was not well understood. In part (a), almost all neglected to take into account the overturning effect of the displaced centre of gravity of the rod, G. So their net restoring moment contained only the spring force and an inevitable error in evaluating the frequency of oscillation. Most realised the need to evaluate the moment of inertia of the rod about point 0 which was equal to 0.51kgm² using the parallel axes theorem. The value of the net restoring moment for a small displacement Θ is 3.453Θ, the resulting angular acceleration for the expression for SHM is 6.776Θ and the resulting frequency of oscillation is 0.414 Hz. In part (b), many candidates did deduce that for no oscillations to occur the restoring moment due to the spring force would be equal to the overturning moment due to the displacement of G (even when this had been ignored in part (a)!) Most of them however became bogged down in the subsequent analysis. The unknown distance OG is then expressed by a quadratic equation from which the only valid root gives a distance for OG of 0.143m

Q7

Tested fundamental understanding of **velocity and acceleration characteristics of a simple mechanism** and was universally poorly done. The linear velocity of point A at an angular rotation of the crank OA of 120 rev/min is 3.77 m/s. From the given velocity diagram, the linear velocity of B (relative to C) is measured at 5.3 cm ie 2.65 m/s on the given scale. The resulting angular velocity of BC, which is the same as that for BD, is therefore 5.3 rads/s

To construct the acceleration diagram for the mechanism, the centripetal accelerations for the members require to be calculated. These are respectively, OA (47.4 m/s²), AB (7.23 m/s²), BC (14.05 m/s²) and CD (14.05 m/s²) or within reasonable proximity. OA has no tangential component of acceleration; the other links do. From o' draw the centripetal acceleration vector o'a' to obtain the point a'. From a' draw the centripetal acceleration vector of B relative to A followed by the tangential acceleration of B relative to A (unknown length and direction). From o' draw the centripetal acceleration vector of B relative to C followed by the tangential acceleration of B relative to C (unknown length and direction). Since both these tangential lines contain the point b', where they intersect determines b'. The acceleration vector b'c'd' is finally drawn geometrically similar to BCD. Tutors and candidates are strongly advised to improve skills in vector representation that examples of this type exemplify for several important reasons, viz they clearly demonstrate *levels of understanding*; they provide a very *physical interpretation* of the more 'abstract' properties of centripetal and tangential acceleration and, although students may be less aware of this, the understanding of the fundamental principles that they embrace are *central to the comprehension of the wider aspects of dynamics*

SUBJECT C106 – THERMODYNAMIC, FLUID AND PROCESS ENGINEERING

General Comments:

The pass-rate for candidates sitting this examination was slightly lower than that of last year and the number of candidates was also less than last year. The paper was designed to be as straightforward as possible yet maintaining the required standard. Any candidate who had prepared conscientiously for the examination should have been able to complete the paper and obtain a reasonable pass.

The examiners realise that many candidates are not fluent in English and find it difficult to express themselves in parts of questions which require them to comment. Consequently allowance is always made for this. Usually this is the only way in which lack of facility in English is a handicap, but Q8 on this paper was misinterpreted by a large proportion of the candidates. The wording of the question was quite clear but it was impossible to give much credit to those who began with the incorrect configuration of the problem.

Many of the examples of poor examination technique, mentioned in the report of last year, still persist. For example, deriving an expression which is given on the examination paper is a waste of time unless it is specifically asked for. Also there were some candidates who had crossed work through without putting anything to replace it. The examiner may well have found some virtue in it.

Comments on Individual Questions:

Q1

This was intended to be an easy question on basic non-flow processes to enable competent candidates to gain confidence. In this it succeeded in that most candidates who knew what they were doing dealt with it well. However, there was a catch in that in parts (iv) and (v) it was necessary to know the mass of gas present in order to calculate the change of internal energy and the quantity of heat transferred. Quite a few did not appreciate this but were still able to obtain a reasonable mark. The mass of gas was found by applying the perfect gas equation to the initial conditions.

Q2

The first part of the question involved drawing a T-s diagram for a pure substance and labelling it as required. As expected most candidates were able to do this. However, a few confused the constant pressure lines with the isotherms of a p-v diagram. The second part of the question was a test of the understanding of the physical implications of the diagram previously drawn. Unfortunately this understanding was lacking in most students. Since the saturation temperature of the fluid was -25 ˚C at the initial pressure and the initial temperature was -10 ˚C then the fluid is at a temperature which is 15 K above the saturation temperature and therefore the state of the fluid is well into the superheat region. Many candidates failed to appreciate this and so were unable to produce any valid work for the rest of the question.

Q3

The first part of the question asked for the cycle efficiency of the Joule gas cycle to be derived. The first three processes of the cycle were described in the question for those unfamiliar with the Joule cycle and the fourth could be deduced. A disturbingly large number of the candidates were unable to formulate the cycle and show it on a property diagram. There were nevertheless, many satisfactory proofs of the cycle efficiency expression produced. The cycle for the numerical part of the question was not a pure Joule cycle because the isentropic efficiencies of both compressor and turbine were involved. Thus it was not possible to simply use the efficiency formula previously derived as many tried to do.

In general the ability of most candidates to handle this type of calculation proved to be poor. In general gas cycle problems are usually best solved by calculating the temperatures at the state points. Many candidates seem reluctant to do this. Of the candidates who progressed to part (b) of the question most were able to deal successfully with the isentropic efficiencies of the compressor and turbine.

Q4

This was a basic question on the combustion process involving a gaseous fuel. The gas composition was given by volume. Avagadro's law is used to relate volumes to the molar quantities in the chemical equations which need to be formulated for the combustion of each of the constituent gases. By this means, the corresponding volumes of oxygen and hence air needed for combustion can be found. Many candidates confused masses and volumes. Credit was given where the chemical equation had been correctly written.

Part (b) of the question involved finding the relative masses of the products when the fuel was burnt with excess air. This meant that the equation of combustion had to be modified and the masses determined from the molar quantities in the equation. Many candidates failed to distinguish between the masses and volumes of the products.

Q5

This is a question on the analysis of the cycle of a steam power plant. Any student who had studied past papers would be well prepared for this question and should know how to deal with it. It was straightforward and was well done by a majority of candidates. However, the practical implications involved are extremely important and it was of concern that whilst many candidates successfully completed the calculations no-one was able to satisfactorily explain the physical significance of their results.

A common error was to confuse this cycle with the Carnot cycle by stopping the condensation process part of the way through at a point such that isentropic compression would give a saturated liquid on entry to the boiler.

Q6

This was a test of the candidate's knowledge of the 1st and 2nd laws of thermodynamics. It consisted of seven short questions requiring short answers. Allowance was made for those unable to explain themselves in the English language. That is, a simple statement of greater than, equal to or less than would gain full marks if the statements were correct. The results were rather disappointing and in particular the answers to parts (d) and (g), where the quantities were properties and therefore undergo no change over a complete cycle, was correctly answered by very few candidates. This was an indication of a poor understanding of the subject by those concerned.

Q7
The question was an exercise in the use of Bernoulli's equation when applied to an orifice plate flowmeter. It was necessary to derive an expression for the flow velocity at the orifice and then to use the continuity equation to calculate the mass flow rate. Those who appreciated what needed to be done did quite well. There was a small group of candidates who had memorised a formula the use of which involved converting the head of mercury into an equivalent head of air. Remembering large formulae is not generally recommended but this was an acceptable alternative method.

Q8
This question was poorly answered possibly because some candidate's grasp of English was not good enough for them to be able to visualise the situation. In retrospect the examination paper would have benefited by the inclusion of a diagram. Many candidates drew a diagram which showed the cone the wrong way up relative to the jet of water. This was an impossible situation because it didn't relate to the questions asked. The mass flow rate of the jet could be found and most candidates were awarded marks for this part.

As the flow moved axially along the outside surface the increasing length of the perimeter caused the depth of the flow to decrease. This thickness of the film was found by the application of the continuity equation. For part (c), the change in the component of velocity in the axial direction will cause a thrust on the cone which is found by determining the rate of change of momentum in this direction. Very few candidates completed parts (b) and (c) satisfactorily.

SUBJECT C107 – ELECTRICAL AND ELECTRONIC ENGINEERING

General Comments:

It is of course realised that English is not the first language of most candidates and every attempt is made to allow for this in spite of the occasional difficulty in interpreting the intended meaning. However there is no excuse for poor penmanship and all candidates should be encouraged to write as clearly as possible. By not reading the questions carefully too many candidates wasted time by giving answers that had not been asked for.

Comments on Individual Questions:

Q1
Some candidates defined amplitude modulation correctly except they implied that the modulating signal had to be a sinewave. A simple question such as this one, although providing valuable practice in analysis, tends to reinforce this error. It is important that students are taught about other modulating signals. For example square or triangular waveforms as well as the general modulating signal.
Solution: depth of modulation 50%, peak voltage = 2 V, mean power = 2.25 W, sideband frequencies = 999 and 1001 kHz.

Q2
Many candidates did not understand that if the current changes instantaneously this means that di/dt is infinite. From the equation this means infinite voltage is required which is impossible.
In part (b) many candidates, instead of reading the question, gave a differential-equation and obtained time-constants and exponential decaying time waveforms.
Solution: I = 0.6 A before and immediately after the switch opens. Then 0.6 A in 1 results in 600 kV.

Q3
Many candidates obtained correct answers without applying minimisation. In part (c) some candidates recognised that P in parts (a) and (b) has the required properties. Although no extra marks were awarded for this, the minimisation was worthwhile since the result is a simpler circuit to draw.

Q4
This question was designed to test both the Maximum Power Transfer theorem and the a.c. analysis of *LC* circuits.
Solution: Maximum power is 1.25 W. When R_L is connected directly the power is 1.11 W. At 50 Hz the coupling network matches the load to the source so the maximum power is transferred. V_o/E = 1/3 at zero frequency and 0 at infinite frequency. At 50 Hz the maximum power is transferred to R_L which gives a maximum value of V_o/E = 0.354.

Q5
Many candidates made mistakes because of a disorganised approach to the analysis and untidy presentation. If resistor kΩ values are used and voltage ratios are formed then the analysis is straight-forward.
Solution: R_{in} = 1 kΩR_{out} = 2 kΩg_m = 36 mS. The Thevinin voltage source = 72 V.

Q6
Few candidates were able to explain the physical significance of the JFET parameters I_{DSS} and V_p as required. Although part (b) presented no particular problems requiring only the solution of two simultaneous equations the final part to determine the biasing components called for the use, in the right order, of a number of simple relationships and this caused problems for many candidates.
Solution: V_p = -4 V, I_{DSS} = 20 mA, R_D = 4 k , R_S = 400 , R_G = 1M .

Q7
Unwisely a number of candidates attempted to solve the problem by Kirchoff analysis and so rarely obtained a correct result. Few candidates knew that the network could be used as a matched 50 attenuator.
Solution: R_1 = 25 , R_2 = 37.5 .

Q8
In part (a) most candidates were able to list ideal properties but many could not give typical values. In view of the importance of operational amplifiers in analogue electronics it is important that candidates have knowledge of the values of the most important parameters. The venerable 741-type is a good basis for this and its parameters typically have simple numerical values which are easily memorised.

In part (b) it is important to justify the simple analysis which results when infinite gain is assumed by stating that – "since there is negative feedback and very high gain then $V^+ = V^-$ ".
Solution: Gain-bandwidth product 1 MHz, slew-rate 1 V/μs, offset voltage 1 mV, output resistance 100 Ω, zero frequency gain 10^5, $V_{out} = 4V_1 + 3V_2 - 4V_3 - 3V_4$.

SUBJECT C108 – SOFTWARE AND INFORMATION SYSTEMS ENGINEERING

Comments on Individual Questions:

Q1
Software Process Models.
This question contributed to the assessment of Learning Outcomes i, ii, and iv.

Most students were able to give a reasonable account of the linear sequential (waterfall) model, and understood that it involves a sequence of distinct, non-overlapping, phases, in which the output from each phase serves as the input to the next. Discussion of its strengths and weaknesses was also good (clearly identified visible deliverables, easy to manage, but dependent on analysis in the early phases correctly identifying the requirements; errors, omissions and requests for changes at later phases expensive to accommodate).

Most students were able to describe an alternative generic model: evolutionary and prototyping approaches being the most popular, though discussion of how these addressed the difficulties of the linear sequential model was not so well done.

The final part of the question asked students to indicate what factors might influence selection of a process model for a project. There were a few good answers to this but most students missed the point of the question: namely that different models have their different strengths and weaknesses and these should influence the model adopted. Possible issues include how well the requirements are understood (a well-understood application in a familiar domain might lend itself to a waterfall approach, a poorly understood set of requirements might suggest exploratory development), the nature of the product (safety critical software might best be approached using a formal systems development approach, for example; while a major new release of an existing product might take a component based reuse-oriented approach) and so on.

Q2
Context Models.
This question contributed to the assessment of Learning Outcomes i and iii.

This question was not generally well done, though there were a handful of good answers. This was somewhat surprising as the introduction to the question makes it clear that a context model does not attempt to describe internal structural or behavioural properties of the system, but rather describes where its boundary lies and what constitutes its environment. Context models are typically described using simple block diagrams, or use case diagrams, or data flow diagrams. The majority of students suggested that an entity life history was an appropriate diagram to describe a system's context. It should be clear that this diagram provides no opportunity to describe either the boundary of a system or provide a succinct summary of its interactions with its environment. Good discussions of context models are provided by Sommerville, Pressman and Pont – all on the reading list for the module, as is the discussion in Booch et al. on the use of use case diagrams to describe a system's context.

Q3
Requirements.
This question contributed to the assessment of Learning Outcomes i, ii, and iv.

About one third of the candidates did not attempt this question, and there were only a few adequate answers in the scripts of those who did. In most cases, the second part of the question was done better than the first: a surprisingly large number of the candidates do not seem to have met the idea of non-functional requirements at all. The kinds of points that were expected are indicated below:

Functional requirements describe services that the system should provide. Functional requirements indicate what the system should do in response to events or inputs, and state what behaviour the system should have in given circumstances. These requirements are often explored using scenarios or use cases. Non-functional requirements are usually described in terms of constraints. Because of this, they are often broader in scope than individual functional requirements, that is, they are often requirements of the whole system. Non-functional requirements relating to the product itself include efficiency requirements (timing, space), usability, reliability and portability requirements; other non-functional requirements may arise from the environment in which the product will operate – what other systems it may need to interact with, for example. Systems will often have to operate or be developed in the context of legal or ethical constraints. There may also be constraints on the development process – for example in safety critical systems the client may require that certain programming language features are not used in the implementation. Again the reader is referred to the discussion in Pressman and in Sommerville.

The second part of the question, on the content and use of a software requirements document, was more reasonably answered. The books by Pressman and by Sommerville provide good discussion and the reader is referred to them.

Q4
Testing.
This question contributed to the assessment of Learning Outcomes i, ii, and iii.

This was the most popular question in the examination, though there were again only a few good answers. Most students understood the difference between black-box and white-box testing, though a surprising number seemed to think that black-box testing had to be system-wide (that is, did not recognise that black-box testing can be employed to test individual software components against the specification of that component). For both parts of the question, on testing individual components and on integration testing, the majority of candidates were able to describe how testing is approached in functionally-decomposed systems, but were much less clear on the situation in object-oriented systems. When the components being tested are single functions with a single call-return interface, and the system as a whole is structured as a call hierarchy, the identification of test cases is easier than in object-oriented systems where the components present many operations that can be invoked, behave differently depending on their state, and where the overall system control structure is not a call hierarchy.

Q5
Project Planning.
This question contributed to the assessment of Learning Outcomes i and iv.

This question was attempted by nearly all the students, and was generally well done. Given that project planning is a topic that is shared with other subjects in the Certificate this was not surprising. A number of students were unable to give a definition of a milestone.

Q6
Object-orientation: specifying and partially implementing an abstract data type.
This question contributed to the assessment of Learning Outcomes i and iii.

There were no good answers to this question, and nearly all of the candidates obtained very low marks. Outcome iii for the subject is that students should be able to "produce simple analyses, designs, implementations and test suites for small systems." This question attempts to assess part of this outcome by having students write a specification for a stack in a programming language such as C++, Java or Ada and give an outline of how the specification can be implemented. The choice of a simple data structure and requirement for only a partial implementation recognised that the design and implementation are difficult to assess under examination conditions. It was expected from the course prerequisites that all candidates would be familiar with stacks, and from the answers given this does seem to have been the case. But the majority of students did not seem to have any idea of what a software component implementing a stack would look like. As object-oriented design is a highly influential paradigm in program development, this inability to produce a simple stack class in a programming language of the student's choice is disappointing. There is a good discussion of abstract data types and object-oriented programming in the book by Pont on the reading list, and Pressman provides a short and useful discussion. The new edition of Jean Bacon's book, also on the reading list, devotes significant space to system design and implementation and begins with a discussion of abstract data types.

Note that the reuse aspect of the question was asking students to define the stack in such a way that elements of any type can be stored on it (in C++ this would mean using a template, in Ada a generic package with a formal private type parameter, in Java or C# specifying that the parameters to the operations on the stack are belong to the base object class). For implementation a few students did recognise that the stack could be implemented using a linked list or an array.

Q7
Architectural design and design patterns.
This question contributed to the assessment of Learning Outcomes i and ii.

This short question was largely a recall question: both architectural design and design patterns are listed as topics in the syllabus for the course, and there is reasonable coverage of both in Pressman and in Sommerville; design patterns are also well-covered in the book by Booch et al. Surprisingly, this question was also done poorly and hardly any of the candidates knew what a design pattern was.

Q8
Software quality and metrics.

This question contributed to the assessment of Learning Outcomes i, ii and iv.

This question was asking students to discuss how quality attributes of a product can be measured. There were some quite reasonable answers, recognising that many of the properties that are easiest to measure for a product do not have a simple relationship with quality attributes we might care about, but attempting to identify what these relationships are. However, many candidates seem to have interpreted the question as a general one about software quality management and there were a number of answers were almost nothing written was of direct relevance to the question being asked.