

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 Certificate examinations and individually for Graduate Diploma and Postgraduate Diploma examinations.

MAY 2004 – CERTIFICATE EXAMINATION

ANALYSIS OF RESULTS BY SUBJECT

Subject	Number of Cands	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Average Mark	%Pass Rate
CERTIFICATE UK									
C101	4						4	18.3	0.0
C102	2	1	1					65.5	100.0
C103	0								
C104	0								
C105	1						1		0.0
C106	2						2	20.5	0.0
C107	2						2	19.5	0.0
C108	0								
O'SEAS									
C101	319		1	3	45	20	250	22.5	15.4
C102	244	30	67	59	46	9	33	53.1	82.8
C103	334	3	21	41	87	22	160	34.6	45.5
C104	260		15	61	114	27	43	43.1	73.1
C105	241	8	25	34	80	10	84	41.3	61.0
C106	168	2	16	14	35	16	85	34.0	39.9
C107	149		1	3	33	5	107	26.1	24.8
C108	31		1	1	5	4	20	25.1	22.6

SUBJECT C101 - MATHEMATICS

General Comments:

The structure of the paper was the same as that of the previous year. The candidates found this a very hard paper. Only a handful of candidates achieved a mark in excess of 50%. Several of the questions appeared beyond the reach of most candidates with certain parts being attempted by virtually no one. Even routine mathematical operations (such as finding the first and second derivatives in question 1) were done badly.

The extensive contextualising of the mathematics in engineering applications might have caused some candidates problems in interpretation; surely the ability to extract the mathematics from the question as worded is part of what one might expect from the candidates who pass the examination. The Fourier series question (number 5) was one of the questions on which candidates made (comparatively) reasonable attempts. perhaps because the question was presented without a context. On the other hand, question 6(a) which actually only requires candidates to determine two vector products was done very poorly and this may have been because of the wording which was context-based. A further problem may have been the common use of parameters rather than numerical values (for example question 1, 3 and 6).

Comments on Individual Questions:

Q1

The initial steps of part (a) of the question should have been routine with the first derivative being found either by a simple application of the product rule or by expanding the brackets; a similar comment applies to finding the second derivative. However, many candidates fell even at this hurdle: the presence of the coefficient α and the parameter ℓ seemed to cause some confusion and many misread the letter ℓ as the number 1. The question asked candidates to locate points of inflection but many conflated the finding of the maximum deflection with the points of inflection rather than finding them separately. Of the few candidates who did manage to keep these two parts separate, it was rare for any to identify properly the points of inflection. Having found where the second derivative was zero, virtually no candidates showed that it changed sign at these points.

Part (b) of the question was done badly almost without exception. Although many candidates seemed to have some idea what l'Hôpital's rule is they found great difficulty in applying it to this question; difficulties appeared in identifying the functions which were be the numerator and denominator of the ratio and even greater difficulty emerged when it came to differentiating the numerator; many candidates differentiated with respect to t rather than R . It would have sufficed simply to quote the Maclaurin series for the exponential function and then apply it to the exponential term in i but many candidates tried to find the Maclaurin series from first principles and invariably made several errors – again usually caused by differentiating with respect to the wrong variable.

Q2

Although there were 16 marks for this question very few candidates scored more than 2 marks. The overwhelming majority made no attempt to evaluate the integral using Simpson's rule: whether this was because they did not know what Simpson's rule is or because they could evaluate the integral exactly and so did not see why it should be

evaluated numerically is impossible to tell. Very few appreciated that the way to determine the actual error in the Simpson's rule estimate is to find the difference between this estimate and the exact value. Although the formula for the error is given quite clearly on the question paper the value M was generally not understood. Several candidates evaluated the error bound for $n = 4$ (rather than finding the error in the way described above); very few realised that the question required the construction of an inequality to be solved for n and of these none could formulate the inequality correctly.

Part (b) of the question was one of the worst attempted parts of the paper. No one even quoted the formula for the position of the centroid of the area. A few candidates found the area of the shape but did not know what to do with this value when they had found it. There were very, very few candidates who provided expressions for the first moments, usually with M_x and M_y the wrong way round. Yet the finding of the centroid of a plane area is a standard task in engineering mathematics.

Q3

Many candidates chose to solve this equation by use of an integrating factor; several of those who did not managed to separate the variables and integrate (although quite a few lost a minus sign in this process). However, applying the initial condition proved far too difficult for a substantial number of them.

Part (b) of the question was rarely completed correctly. Many candidates correctly determined the integrating factor but again the initial conditions proved problematic. Some candidates were confused by the notation, thinking that h_0 was the value of h at time $t = 0$ (overlooking the fact that the tank was initially empty and so $h(0) = 0$). As a consequence very few correct graphs were drawn because many candidates did not have the correct function to sketch.

Q4

In part (a) of the question there was confusion amongst some candidates about the formula for the volume of a cylinder in terms of the diameter rather than the radius. A greater problem was that many students did not appreciate that they should use the result that δV is approximately $\frac{\partial V}{\partial r} \delta r + \frac{\partial V}{\partial h} \delta h$.

Many candidates did not know where to start with part (b) of the question and few of those that did appeared to appreciate how to incorporate the fact that p is constant on an isobar.

Q5

Unusually, compared with previous years, the Fourier series question was one of the questions on which candidates fared better. The integration by parts that was required to determine the coefficients was not too difficult. There were some problems with using $\cos n\pi = (-1)^n$.

Q6

It appears that many candidates did not realise that in effect all they were being asked to do in part (a) of the question was to determine two vector products.

Part (b) of this question was probably the question that candidates found the most difficult along with part (b) of Question 2. Very few had any idea how to determine the point of intersection of the two lines and even fewer made anything like a reasonable effort to find the angle between the directions of the lines. If they understood the interpretation of the vector equation of a line then this part of the question should have proved straightforward.

Q7

Many candidates managed to show that the equations do not have a unique solution. Others carried out the work to show this result (that is they either found that the determinant of the coefficient matrix was zero or that the last row of Gaussian elimination produces all zeros) but then did not appreciate that this meant there was not a unique solution. Despite the wording of the question, some candidates thought they had found a unique solution. The majority of those candidates who found there was no solution stopped at this point – it seems they did not know how to produce a parametric solution by setting $x_3 = t$, say, and then back-substituting.

Apart from the inevitable forest of algebraic errors in finding the characteristic equation, most candidates knew how to find the eigenvalues. However, determining the eigenvectors was beyond virtually everyone. The most commonly presented eigenvector was $(0, 0, 0)$, which many candidates offered as an eigenvector for each eigenvalue. The fact that an eigenvector must not be the zero vector has obviously not been understood. Clearly, without having found appropriate eigenvectors it was impossible for candidates to show that these eigenvectors were mutually perpendicular.

Q8

Part (a) of the question was on a par with part (b) of Question 6 as the second worst answered question. It was very rare to see a candidate considering the Poisson distribution, rarer still to see any calculations done with the Poisson formula and there were scarcely any correct answer to this part.

In part (b) of the question several candidates recognised that they were required to employ the binomial distribution and managed to calculate correctly the probability that a sample contained no defective items and the probability of one defective item. However, very few were able to put these results together to determine the probability that a batch is accepted – most simply added the two probabilities instead of using $p(0) + p(1) \times p(0)$.

Q9

There were several reasonable attempts at this question, particularly parts (a) to (c). Part (d), which requires candidates to ‘work backwards’ from values within the tables to the argument, did cause severe problems. As a consequence, 5 marks out of 7 was the modal mark for those candidates who made reasonable progress with the question.

Q10

For part (a) of the question many candidates did not use the information given about the equivalence of an implication and an ‘and’ operation to complete the final step of their proofs, although they did show that they could manipulate truth tables reasonably well.

There were two main deficiencies exhibited by those who attempted part (b) of the question. The first was that several candidates tried to establish the result using truth tables rather than use Venn diagrams as suggested and came a cropper. The second, which applied to those who did attempt to use Venn diagrams, was that they only showed the result in one direction (that is they started from $A \cap B = \emptyset$ and found that the result was true) and did not attempt it in the other direction. Some candidates started with two sets A and B which had a non-empty intersection and found that the result was not true and gave up at that point.

SUBJECT C102 – ENGINEERING MATERIALS

Comments on Individual Questions:

Q1

This question concerned atomic bonding mechanisms and the related properties of the materials. Most candidates were able to give a simple description of the bonding mechanism, but there were very few candidates who demonstrated a complete understanding of the electronic arrangements. No candidates mentioned that bonds can show partial ionic and partial covalent character. The last part of the question relating mechanical and electrical properties to prevalent bond type was answered well by the majority, although an obvious problem arose when candidates tried to describe the low strength and stiffness of polymers in terms of the 'strong' interchain covalent bonds. The role of the 'weak' intrachain dipole bonds was a question which was not well understood.

Q2

A very similar question to last year, and the same problems and difficulties appear once again. Calculations of stiffness and UTS were generally fine (albeit noting that many candidates have problems with the units), but the concept of proof stress confounds many. The introductory section, requiring candidates to describe a tensile test experiment, was done well but marks would have been higher if more detail, e.g. how is extension measured, was included.

Q3

This question on creep was the most difficult for all the candidates. It is obviously not well covered by the centres. Many candidates did not read the question, and in (b) described how to perform a creep test at jet engine operating conditions. There were very few candidates who recognised that steady state creep can be described by an equation with a stress exponent and Arrhenius type behaviour with temperature. This equation can then be used to extrapolate lower temperature and stress experiments to the required operating conditions.

Q4

A regular question in which many candidates scored high marks. Phase diagrams were generally very good, with the only common flaw being one where the composition axis was reversed. Diagrams of microstructural evolution left much to be desired, but the basic concept of a primary β phase surrounded by a lamellar α/β eutectic was achieved by most. Reiterating comments made in previous years, the lever rule calculation caused most problems in this question, with many long winded derivations of a very simple equation.

Q5

This question on semiconductors was done well by a large proportion of the candidates. Virtually all candidates were able to describe the concept of a band gap between the valence and conductor bands, but only one or two were able to explain the acceptor levels (p-type) or donor levels (n-type) that give rise to increased conductivity in the extrinsic semiconductors. Variation of thermal conductivity was done well for pure Cu and pure Si, but doped Si caused many problems. No candidates were able to describe completely the increase in conductivity as electrons in the donor states are excited into the CB, followed by a plateau once the donor states are exhausted, and then a further increase in conductivity at high temperature as intrinsic conductance occurs. The section on LED was answered well, with most candidates giving good descriptions. Reasons for the colour of the emitted light were less good, with many saying that the colour is determined by the colour of the plastic lid on top of the device - correct, but not really what was expected.

Q6

A new type of question on material selection and recycling issues. Many candidates lost marks by not mentioning any manufacturing processes or issues for the items being discussed. Answers to the recycling part of the question were mixed - some candidates showed a good grasp of collection / separation / remanufacture issues, but there were a lot of answers along the lines of: "This can be recycled".

SUBJECT C103 – ENGINEERING SCIENCE**Comments on Individual Questions:****Q1**

Most candidates were familiar with the procedure required to derive the equation for the tangential strain on the surface of a spherical shell subjected to an internal pressure, required in part (a) of this question. Of those students who attempted the question almost all were able to complete the derivation correctly. Most candidates were able to substitute the numerical information given in part (b) of the question into the formula provided in part (a) to obtain the strain value. Most were also able to derive or recall the relationship between volumetric and linear strain. A significant proportion of candidates had difficulty in relating the volumetric strain and bulk modulus to the volume of water pumped into the shell. Subsequent numerical errors also meant that only a few candidates obtained the correct value for the volume of water pumped into the pressure vessel of 0.4795 dm^3 .

Q2

The approach adopted by most candidates to solving this question was to consider the equilibrium of the tensions in the two cables with the weight of the beam W and the applied force P . To find the inclination angle of the beam α required for part (a) of the question, the simplest approach was to take moments about point A which resulted in a single equation for α . Most candidates, however, chose to resolve the forces either in the horizontal and vertical directions or parallel and normal to the beam. A third equation is then required as the first two equations involve the unknown tensions in the two cables. This third equation was usually obtained by taking moments about either one of the points of attachment of the cables to the beam or about point G. Frequently errors were made in this third equation either because the distances between the point about which

moments were taken and the line of action of the forces was incorrectly worked out or candidates incorrectly believed that the distance required for computation of the moment was to the point of action of the force rather than the normal distance to the forces line of action. The three equations then required solution and many candidates were either defeated by the algebra or made algebraic errors and so correct expressions for α were rarely obtained with this approach. Students are therefore advised to give careful consideration to the most appropriate resolution and moment equations to consider for a particular problem so as to avoid unnecessary complex algebra.

A second relatively simple approach was to recognise that the resultant of the P and W forces must act through point O for equilibrium. The angle α can then be obtained purely through geometry. Only a few candidates adopted this approach some of whom were successful.

Part (b) of the question was correctly solved by the majority of candidates. The most common approach was to resolve the forces in the horizontal and vertical directions and to then solve these two equations for the two tensions. Alternatively the forces could be resolved in directions parallel and normal to the beam. Some candidates tried to obtain each tension directly by taking moments about the point of attachment of each cable to the beam. This approach although direct was however less successful because of the difficulties in determining the distances required for the moment of each force. Some candidates also incorrectly assumed that the tensions in the two cables were equal.

Q3

The complexity of this question is substantially reduced once its symmetrical property is recognised. Some candidates failed to make use of the symmetry even though it is stated in the question. Further candidates did not make use of the symmetry at the outset which led to unnecessarily complex solutions. The simplest approach to part (a) of the question was to consider the linear accelerations of the centre body and either the left or right mass and to also consider the angular acceleration of either of the fixed pulleys. The majority of candidates were able to derive these three equations correctly. Frequent errors were made however in finding the ratio between the accelerations of the centre and left or right hand masses. A significant number of candidates assumed that this ratio was either one or two. To get the correct relationship the fact that the cable has a constant length throughout should be utilised and it is then found that the ratio depends on the angle of the cable α . Generally though most candidates obtained the majority of the marks for part (a).

To obtain the answer to part (b) it needs to be recognised that, if the system is in equilibrium, the acceleration derived in part (a) should be zero. The correct answer for α of 30 degrees is then easily obtained. Many candidates did not attempt part (b) of the question apparently not realising that the answer could be obtained simply by using the answer given for part (a).

Q4

The majority of candidates realised that the answer required for this question could be obtained by taking moments about point O . Some candidates had difficulty in determining the distance between point O and the line of action of the weight of the block. It was also necessary to determine the moment of inertia of the block about point O using the expression given in the question about point G and the parallel axes theorem. Most candidates were aware of this although some were unable to determine the distance between points O and G correctly. An alternative approach was to take

moments about point G. This avoided the use of the parallel axes theorem, but required the determination of the reaction force at O through resolution of the vertical forces and then relating the linear and rotational accelerations. This more complex approach was generally less successful. A small number of candidates attempted to solve the problem by using an energy approach. This would be a sensible if the question had asked for the angular velocity or if the angular acceleration were constant. In this case though the angular acceleration decreases with the applied moment due to the blocks weight as θ increases and this makes an energy approach to the problem significantly more complex.

Q5

Most candidates attempting part (a) of the question were clearly familiar with the derivation required and had no difficulty in performing the required integral to obtain the expression given in the question.

About half the candidates attempting part (b) of the question recognised the expression given as being the work done or increase in specific internal energy for an adiabatic process. They then proceeded to repeat the procedure used in part (a) but for an adiabatic process. This question does not however relate to an adiabatic process and hence this form of solution on its own is incorrect. The remaining candidates adopted the correct approach and used the fact that the change in specific internal energy could be obtained using the specific heat at constant volume and the change in temperature during the process. Further use of the equation of state then resulted in the answer given in the question.

Q6

The majority of candidates showed skill in solving this type of question. However, many candidates chose to derive an expression for the force acting on the gate first rather than the expression for the torque asked for in part (a) of the question. Many candidates were successful in obtaining the required expression though, even if the amount of algebra used was far greater than necessary. Incorrect solutions usually resulted from algebraic errors.

To obtain the answer to part (b) it is necessary to realise that the torque found in part (a) would be zero at the point where the gate opens. This was realised by the majority attempting this part of the question and most obtained the correct value for d of 6.667m. A lot of candidates didn't attempt part (b) of the question even though they had been successful with part (a), possibly because they had failed to read part (b) to the question.

Q7

Many candidates attempts at this question were far more complex than necessary, because they failed to utilise symmetry. The circuit shown is completely symmetric and hence in part (a) nodes C and D and nodes B and E can be connected together as they will have the same voltage potential. The circuit then becomes a relatively straightforward voltage divider and the voltages at each node can be found. The correct values for the voltage differences are $V_{OB} = V_{OE} = 7.714\text{v}$, $V_{OC} = V_{OD} = 4.286\text{v}$, $V_{OF} = 6.857\text{v}$ and $V_{OG} = 5.143\text{v}$.

Symmetry can also be utilised in part (b) where the nodes A, C and D and nodes B, E and G can be connected together to once again produce a voltage divider. A greater proportion of candidates were able to recognise the symmetry for this part of the

question and hence to obtain the correct answers of $V_{OA} = V_{OC} = V_{OD} = 4.8\text{v}$ and $V_{OB} = V_{OE} = V_{OG} = 7.2\text{v}$.

For candidates who did not utilise symmetry, six equations for the six unknown voltages were derived, but their solution was generally too complex or time consuming to be successful.

Q8

The majority of candidates were able to sketch the wave form required in part (a) resulting from the full wave rectification circuit shown in the question. In some cases marks had to be deducted though because the sketched wave form was insufficiently detailed. A few candidates incorrectly showed the output voltage rising during the periods when the power is being drawn from the capacitor.

In parts (b) and (c) only a few candidates realised that changing the resistance values would effect both the DC and AC components of the voltage across the load resistor with roughly equal numbers of candidates commenting on the change to either just the DC or just the AC component.

In part (d) most candidates recognised the role of the capacitor and that increasing its value would result in reduction of the AC ripple voltage.

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 questions 3 and 4.

Comments on Individual Questions:

Q1

The characteristics and responsibilities of Professional Engineers - the answer should include most of the following broad points

- Possess education in an engineering specialty
- Possess knowledge in an engineering specialty
- Possess skills in an engineering specialty
- Keep abreast of recent developments and technological change
- Be willing to advance professional knowledge and share this with colleagues
- Be willing to advance ideals and share this with colleagues
- Be willing to advance practice and share this with colleagues
- Have a sense of responsibility and service to society
- Have a sense of responsibility and service to employers
- Have a sense of responsibility and service to clients

- Follow established codes of ethics for the profession as specified by the appropriate institution

Answers to this section were often very garbled and not described in a systematic way such as the above. Often a simple description of the activities of an engineer were described, rather than the professional attributes.

A typical answer should include some of the features of the following description taken from the recommended textbook by Wright "Introduction to Engineering" Professional engineers are expected to possess education, knowledge, and skills in an engineering specialty that exceed those of the general public. They must be willing to stay abreast of discoveries and technological changes by participation in professional meetings and continuing education. They must also possess a willingness to advance professional knowledge, ideals, and practice and to share their knowledge with their peers. Professional engineers must have a sense of responsibility and service to society and to their employers and clients, and they must act honourably in their dealings with others. They must be willing to follow established codes of ethics for their profession and to guard their professional integrity and ideals and those of their profession.

Often candidates gave repetitive accounts of one of these points. More attention should be given to planning the points to be made in the answer before writing the final text as concisely as possible.

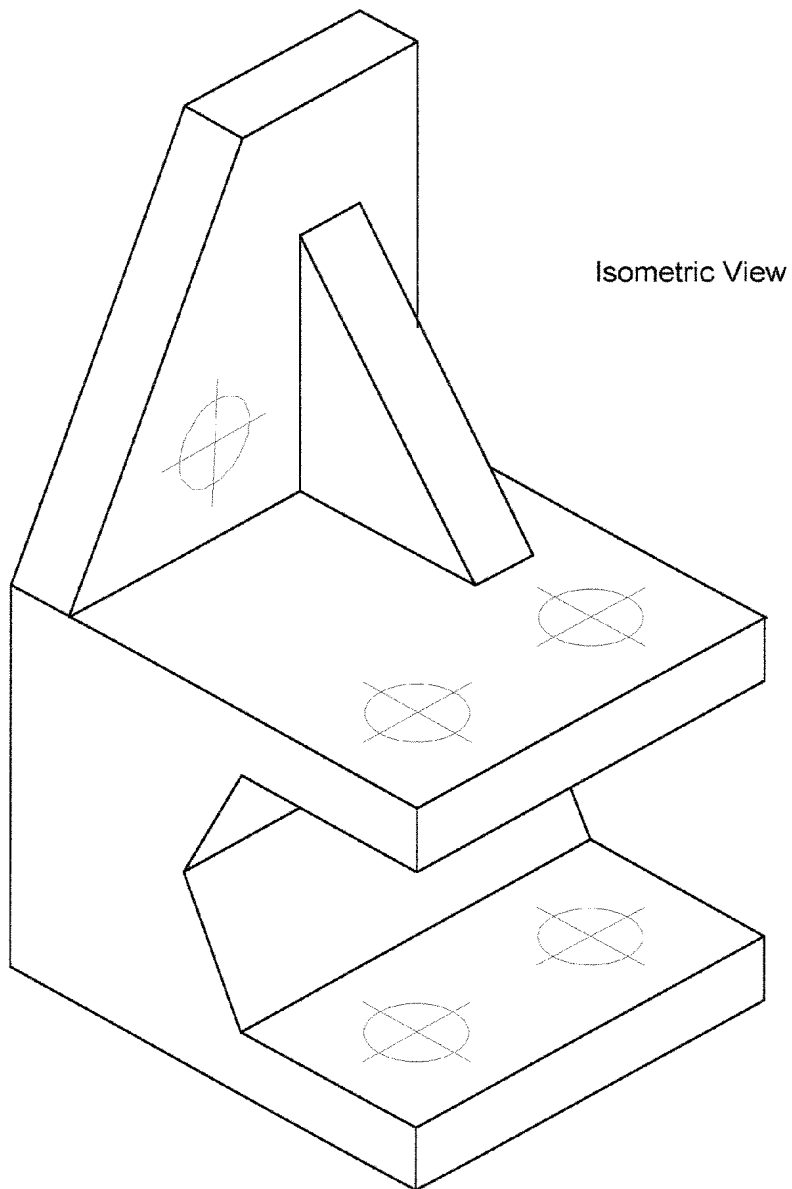
Q2

The most appropriate missing words are identified as follows:

1. auxiliary view
2. DCF
3. maximin criterion
4. search techniques
5. pessimistic time
6. on-line transaction
7. dynamic
8. distributed
9. logical
10. algorithm

Q3

- (a) (i) The controlled end surface is required to lie between two planes 0.04 mm apart and perpendicular to the left hand cylindrical portion (datum axis A)
- (ii) Permissible value of surface roughness with a maximum value
- (iii) Binary logic element NOT (negator)
- (iv) Cylinder with cushion (single fixed)



(b) Sometimes preliminary sketches were omitted even though the question clearly requested these. The best responses used the isometric graph paper provided, but often the view was 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.

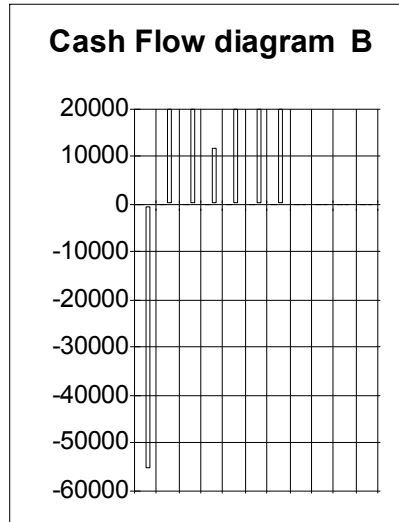
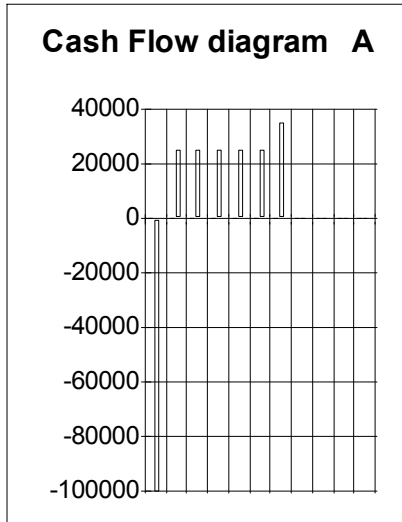
Critical path = 1 --2--3 -- 5 -- 6 --8-- 9--10 and the expected project completion time = **300 days**

Activity	time	ES	EF	LS	LF	Slack	CPath				
1 - 2	40	0	40	0	40	0	*				
2 - 3	100	40	140	40	140	0	*				
2 - 4	40	40	80	120	160	80					
2 - 5	80	40	120	80	160	40					
3 - 4	0	140	140	160	160	20					
3 - 5	20	140	160	140	160	0	*				
3 - 6	60	140	200	160	220	20					
4 - 7	80	140	220	160	240	20					
5 - 6	60	160	220	160	220	0	*				
6 - 8	60	220	280	220	280	0	*				
6 - 9	20	220	240	260	280	40					
7 - 9	40	220	260	240	280	20					
8 - 9	0	280	280	280	280	0	*				
9 - 10	20	280	300	280	300	0	*				

(b) The purpose of project crashing is to shorten the project duration at the least possible cost. To achieve this , we need to see which activity **on the critical path** has the minimum crash cost, and reduce this activity duration by the maximum amount or until another path becomes critical. If more than one path is critical, both paths must be reduced by the same amount simultaneously. This process is repeated until the crashing objective is reached.

Section (b) was seldom described correctly

Q5



The cash flow diagrams were usually drawn correctly. The most common mistake was to ignore the negative initial outlay of £100000 (proposal A) or £55000 (proposal B). Some candidates ignored the time value of money and simply used the nominal values

Proposal A

EOY	£ in/out	NPV	Cumulative NPV for
EOY	EOY	EOY	i = 5%
0	-100000	-100000	-100000
1	25000	23809.5	-76191
2	25000	22675.7	-53515
3	25000	21595.9	-31919
4	25000	20567.6	-11351
5	25000	19588.2	8237
6	35000	26117.5	34355 ← required values at end of year 6
Total	60000		

Proposal B

EOY	£ in/out	NPV	Cumulative NPV for
EOY	EOY	EOY	i = 5%
0	-55000	-55000	-55000
1	20000	19047.6	-35952
2	20000	18140.6	-17811
3	12000	10366.1	-7445
4	20000	16454	9009
5	20000	15670.5	24680
6	20000	14924.3	39604 ← required values at end of year 6
Total	57000		

Using the NPV approach gives the present value for proposal A as £34355, and for proposal B as £39604, so that proposal B is better by an amount = 39604 - 34355 = £5249.

The effect of inflation is to lower still further the net present value of any future receipts and costs. This would make B even more attractive, although inflation is usually ignored in NPV analyses.

Many candidates confused the inflation rate and interest rate when commenting on this.

Q6

By its nature the answer to this question is specific to each individual examination candidate.

Ideally, a flowchart, pseudocode, or other planning 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.

Q7

(a) These equations are used in numerical differentiation and are based on both the following :-

- (i) the central difference method
- (ii) the Taylor series expansion **including** second order quantities

Using a simple power function e.g. $f(x) = x^2$ and with $\Delta x = 1$, so to find the first and second differentials at, say, $x = 3$

x	f(x)
1 ← f(x-2Δx)	1
2 ← f(x-Δx)	4
3 ← f(x)	9
4 ← f(x+Δx)	16
5 ← f(x+2Δx)	25

$$\frac{df(x)}{dx} \approx \frac{-f(x+2\Delta x) + 8f(x+\Delta x) - 8f(x-\Delta x) + f(x-2\Delta x)}{12\Delta x}$$

$$= \frac{-25 + 8 \times 16 - 8 \times 4 + 1}{12 \times 1} = 6$$

$$\frac{d^2 f(x)}{dx^2} \approx \frac{-f(x+2\Delta x) + 16f(x+\Delta x) - 30f(x) + 16f(x-\Delta x) - f(x-2\Delta x)}{12(\Delta x)^2}$$

$$= \frac{-25 + 16 \times 16 - 30 \times 9 + 16 \times 4 - 1}{12 \times (1^2)} = \frac{24}{12} = 2$$

The purpose of the equations and the above calculation reflecting their numerical nature was rarely identified clearly.

(b)

machine breakdowns per week	probability	cumulative probability	Random number Range
0	0.2	0.2	1-20
1	0.2	0.4	21-40
2	0.3	0.7	41-70
3	0.2	0.9	71-90
4	0.1	1.0	91-100

Week	RN from column (2)	Breakdowns each week	Cumulative Breakdowns	Current Average Breakdowns
1	92	4	4	4
2	69	2	6	3
3	97	4	10	3.33
4	72	3	13	4.25
5	17	0	13	2.6
6	93	4	17	2.83
7	52	2	19	2.71
8	85	3	22	2.75
9	2	0	22	2.44
10	41	2	24	2.4

Total breakdowns = 26 over 10 trials (weeks) i.e. average = 2.6 breakdowns/week. This value is clearly not the steady state value so that many more trials would be required. From the input distribution, it can be observed that the expected long term value would be $(0 \times 0.2 + 1 \times 0.2 + 2 \times 0.3 + 3 \times 0.2 + 4 \times 0.1) = 1.8$ breakdowns/week.

This section (b) was often attempted satisfactorily, although very few candidates made the point that many more trials would be required to get a reasonable estimate.

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 7 questions that fully covered the syllabus.

Candidate numbers, pass rates, average mark and the proportion of candidates who were quite unprepared for the Examination was also similar to the corresponding figures for 2003. Prospective candidates should continue to apply a rational self-assessment procedure in determining their suitability for presentation at the Examination to reduce this latter figure further.

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. 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

Assesses understanding of equilibrium and free-body diagrams for a simple pinned frame and was generally well done. Bow's Notation and graphical analysis should be discouraged for this simple example. Candidates are expected to quickly evaluate the relevant dimensions of the frame eg if AB (=AD) is taken as unit length, then the horizontal distance from A to the 10kN load line is $1 \times \cos 30^\circ$ ie 0.866. Moments about B then give the value of the horizontal force $P = 8.66\text{kN}$. Hence the vertical and horizontal reactions at B are, respectively, 10kN and 8.66kN. By observation, it should be clear that the force in member AC = 0 since there is no other force at C in the AC direction. It should be equally obvious that the force in members BC and CD must also be equal. *Candidates should take a few seconds to reflect on observations such as this and not simply charge on with calculations which, if containing a numerical error, lead to an absurd answer!* It is also important for candidates to correctly discriminate between tensile and compressive forces in the members – there were too many examples where this was incorrectly assessed. Resolution of forces at point B gives the force in AB = 5kN (tens) and the force in BC = 17.3kN (comp). Resolution of forces at point A gives the force in AD = 10kN (tens)

Q2

Features static indeterminacy in tension/compression including, in this instance, compatibility with thermal effects. There is an emphasis on the displacement diagram for the system in Part (b) which the great majority of candidates appeared unable to assemble or comprehend. *Tutors should spend some time illustrating how 'free' thermal expansion and resulting deformation is related in cases such as this as they will continue to be included in the examinable scope of work.* For Part (a), the 'free' thermal expansion of AB is wholly prevented by the assumed total rigidity of CD. Therefore, the strain in AB is αt and the resulting stress is $E\alpha t$ ie $240 \text{ MN/m}^2(\text{comp})$. The force in CD is not equal to the force in AB as many candidates wrongly assumed since there will be a horizontal reaction force at the pivot O. Moments about O – actually stated in Part (b) of the question - will provide the required equilibrium condition ie the force in CD (tens) is half the value of the force in AB (comp). For Part (b), there will be a small elastic extension of CD allowing some of the 'free' thermal expansion of AB to take place. A sketch of the rigid lever rotated from its original position OBD to this new position OB'D' will then show that if the resulting compression of AB is say, δ , then the displacement of the point B is $(L\alpha t - \delta)$ and the extension of CD is $2(L\alpha t - \delta)$. Hence, using the equilibrium condition that the force in AB = 2 x the force in CD, and that from Hooke's Law, extension/compression = (PL/AE) , the stress in CD is calculated as $96 \text{ MN/m}^2(\text{tens})$ and therefore the stress in AB = $192 \text{ MN/m}^2(\text{comp})$

A further point that tutors should impress upon candidates is the usage of preferred units for stress. The preferred units for stress are MN/m^2 (or N/mm^2 which gives the same number) and not, as some examples for Part(a) were given, $240 \times 10^3 \text{ kN/m}^2$, 0.24 GN/m^2 etc.

Q3

Assesses the fundamental concepts of stress at a point in a shaft subject to axial torsion and bending. Candidates continue to show 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 shear stress due to the torque acting alone, from the simple torsion formula, is 61.1 MN/m^2 . The bending stress due to the bending moment acting alone, from the simple bending formula, is 203.7 MN/m^2 (either tension or compression depending upon whether you are considering the top or the bottom of the shaft). Hence, for the combined loading at a point on the (top) surface of the shaft, there is an axial tensile stress of 203.7 MN/m^2 along with a shear stress of 61.1 MN/m^2 on the same plane, and on the plane at right angles to that, a direct stress of zero along with a shear stress of 61.1 MN/m^2 . The Mohr circle can now readily be sketched from these values and the principal stresses calculated from the extremities of the circle on the x-axis - namely 220.7 MN/m^2 (tens) and 16.9 MN/m^2 (comp). The maximum shear stress due to the combined loading is 118.8 MN/m^2 (ie the radius of the Mohr circle in those terms). The directions of the principal stresses need to be shown on a sketch of the shaft - mutually perpendicular to each other and with the larger principal stress at 15.5° to the axis of the shaft. The planes of maximum shear stress can always be simply stated as being at 45° to the principal planes.

Q4

Assesses understanding of shear force and bending moment distributions for a statically determinate beam problem, and the conversion from static determinacy to static indeterminacy by changing the support condition from a simple support to a built-in condition. Most candidates demonstrated good understanding of shear force and bending moment diagrams and the conversion to static indeterminacy. For parts (a) and (b), the reactions at A and C are 5.5 kN and 20.5 kN respectively. Shear force values are 5.5 kN (between A and B), -10.5 kN (between B and C), and varying linearly from 10 kN at C to zero at D. Bending moments at A and D are necessarily zero, 5.5 kNm at B and -5 kNm at C, varying parabolically from C to D. (*The sign conventions can clearly be reversed for both shear and bending*) When the beam support at A is changed from a simple support to a built-in condition, there is now an unknown reaction at C, along with an unknown reaction and an unknown fixing moment in the 'wall' at A - ie 3 unknowns, therefore statically indeterminate. The double integration of the bending moment terms - incorporating the Macauley notation - can be carried out, with the boundary conditions of zero slope at A and zero deflections at A and C used to indicate the evaluation of the unknown reactions and constants of integration. Some candidates wasted valuable time by carrying out a complete analysis of the statically indeterminate case when the question stated specifically not to do so!

Q5

Assesses the concept of energy, circular motion and centrifugal force and was very poorly done - almost exclusively on the basis that many candidates assumed that the critical condition for the car was that its velocity at the top of the loop should be zero. Apparently, those candidates did not pause even for a second to realise what would actually happen to the car if it literally stopped moving when upside down at the top of the loop! (*refer to Comment on Q1 regarding reflecting on the outcome of assumptions made*). Of course, the critical condition is the minimum velocity of the car for it to remain in contact with the track as it travels round the loop. That is, when the gravitational force ($m.g$) just equals the centrifugal force ($m.v^2/r$) ie when $v^2 = g.r$ or $v = 12.13 \text{ m/s}$. The energy of the car at the top of the loop is therefore the kinetic energy at that minimum velocity plus the potential energy from being 30 m above the ground. This can then be equated to the total energy (ie kinetic + potential) at the top of the hill from which the unknown height of hill is found to be 36.2 m .

Q6

Assesses the torsional stiffness of a stepped, circular-section cantilevered shaft and the evaluation of its torsional SHM when carrying a rotor on its free end. It is acceptable to consider only the inertia of the rotor (I) and ignore the inertia of the shaft for this case. Many candidates wrongly assumed that a torque applied at C is the sum of a torque carried on section AB plus a torque carried on BC, when in fact a torque applied at C will be the same on both sections. However, the angle of twist experienced at C will be the sum of the angle of twist over AB plus the (different) angle of twist over BC. So the stiffness of the shaft at C will be T/Θ where Θ is the total angle of twist. Inserting the appropriate values of G , J and L for the two sections into the simple torsion formula enables the stiffness (k) at C to be found to be $38.8 \times 10^3 \text{ Nm/rad}$. The frequency of the torsional vibration of the system is then given by the expression $(1/2\pi)\sqrt{k/I}$ and is found to be 19.1 Hz.

Q7

Assesses fundamental understanding of velocity and acceleration characteristics of a simple mechanism and was universally poorly done. In particular this year, there appears to be a singular lack of understanding of vector representation for both velocity and acceleration, with very few candidates attempting to illustrate either of these properties for the mechanism. The linear velocity of point A at an angular rotation of the crank OA of 120 rev/min is 0.63 m/s. The included angle between the con rod and the horizontal line OB is calculated as 13.63° so enabling the velocity diagram to be quickly sketched and the velocity of B relative to A (0.46m/s) and the velocity of B relative to the fixed point O (0.34m/s from right to left) to be evaluated. The centripetal acceleration of A (7.94m/s^2), and of B relative to A (1.41m/s^2) can now be drawn on the Worksheet, followed by inserting the line representing the tangential acceleration of B relative to A (perpendicular to the centripetal component). A horizontal line from the point o' to intersect the tangential component line gives the vector representing the acceleration of B (5.6 m/s^2). Since this vector indicates the acceleration of B is from left to right ie opposite to the direction of the velocity of B, then B is decelerating. Finally, the angular acceleration of the conrod AB is determined by dividing the tangential acceleration of B relative to A by the length of the conrod ie $5.5/0.15 \text{ rad/s}^2$ or 36.7 rad/s^2

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 *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*. *It is also important to add that examples of this type will continue to be included in the examinable scope of work.*

SUBJECT C106 – THERMODYNAMIC, FLUID AND PROCESS ENGINEERING**General Comments:**

A large number of very able candidates performed well in the examinations with many obtaining marks greater than 60%. However, the low average mark arose because of a long tail of weak and unprepared candidates, many of whom gained a mark of less than 10%. The weaker candidates were content to answer only selected parts of questions even though by doing so they forfeited other marks available in the question. A common

problem among these candidates was the frequent inclusion of careless arithmetic and algebraic errors in solutions, suggesting that they did not check their own work, even when the answer obtained was highly improbable. In contrast, the quality of answers given by the best candidates was very high, demonstrating a good understanding of thermodynamics and fluid mechanics and generally providing accurate numerical calculations.

There is some evidence that many candidates are confused by the change in work definition in the first law of thermodynamics from work done by the system (control volume) to work done on the system control (control volume). Some candidates took the trouble to clearly define the convention they were using in their solutions. However, other did not, leading the frequent appearance of work quantities with the wrong sign. In many cases, the sign was simply changed without comment when it was thought necessary to do so. Several candidates used temperatures in °C rather than K calculations. While this is not a problem for temperature differences, it produces major errors when temperature ratios are involved. Also, several candidates appeared to assume that all adiabatic processes are isentropic processes and sometimes that they are isothermal processes also. A frequent error made was to mix steam properties from tables with properties derived from perfect gas equations, often using the perfect gas properties for air in steam calculations. Also, there were very many careless transcription errors when extracting data from property tables. These produced wildly inaccurate values for steam properties in several questions.

Comments on Individual Questions:

Q1

Many candidates offered good solutions, producing correct property diagrams for part (a) and showing accurate manipulation skills in part (b). However, for others, the diagrams of part (a) were often inaccurate and the manipulation of expressions caused difficulties and was made inaccurate by careless errors. Many candidates ignored the mass of gas in the cycle and simply assumed this to be unity. A large number appeared confused when generating an expression for Q_{out} , the heat rejected in the cycle. They used the first law for the system but overlooked that the Q term refers to the heat added to the system and not heat rejected. This resulted in an incorrect sign for the expression derived.

Q2

This question was generally well answered with many completely correct answers. Most candidates simply recalled the equations for the hydrostatic pressure on the submerged surface and the depth of the centre of pressure and its location for a plane rectangle. Only a few derived the expressions required. A surprising number of candidates did not provide the answers requested in the question even though their work would have allowed them to do so. For example instead of the resultant force, the two forces contributing to the resultant were given. Similarly, the moment equation was given rather than the net moment of the forces. Also, the direction of the resultant moment was not always made clear. A number of candidates seemed completely unfamiliar with questions of this type.

The numerical answers are:

(a) 42, 269 N

(b) 59, 124 Nm (*anti-clockwise in Fig. Q2*)

Q3

Many candidates were able to correctly derive the expression for entropy change given in part (a) but did not seem to know how to evaluate the calculations in part (b). In the derivation, a considerable number of candidates did not properly describe the work term dW in the differential form of the first law ($dQ + dW = dU$) as work added to the system and hence the term PdV should be negative. This produced an error in sign which was simply ignored later in the derivation when the expression required was not forthcoming. In part (b) a number of candidates used the Bernoulli equation for an incompressible fluid between X and Y instead of the steady state, steady flow energy equation. A large number of calculation errors were caused by not reducing the units in an equation to standard SI units. Also, several candidates used temperatures in °C instead of K for the temperature ratio calculation. There was frequent confusion by candidates between adiabatic flow and isentropic flow while others assumed work was done in the duct between X and Y. A number of candidates seemed unable to find values for the specific heat and gas constraint for air. Several incorrectly used the value for the universal gas constraint directly in the calculations. Also, many candidates did not appear to understand the term entropy change and tried in vain to calculate a value for mass.

The numerical answers are:

(b) (i) 95.1 m/s

(b) (ii) 0.1064 kJ/kgK ; flow from Y to X

Q4

The calculations in this question were dominated by many careless transcription errors from steam tables. Values were frequently used from the wrong rows and the wrong columns in the tables and often extrapolation rather than interpolation was performed between table entries. Several candidates calculated the exit condition at the turbine as having a dryness fraction (quality) $x > 1.0$ and proceeded to use this to determine steam properties. This extrapolation process introduces significant numerical errors because of the non-linear property relations for steam close to the saturation boundary. Candidates should of course have realised that $x > 1.0$ indicates that the steam is still superheated and interpolated the superheat tables for the turbine exit property values. A surprising number of candidates used a mixture of steam table entries and perfect gas equations to determine steam properties, usually with numerical values for air in the gas equations. Very few candidates were able to produce accurate block diagrams for part (a) (ii), and particularly for the reactor/boiler and condenser/district heating processes. There was little evidence that candidates understood how to perform heat balance calculations for the reactor/boiler. This resulted in very few correct answers for the calculation of mass flow rate for the carbon dioxide coolant in part (b). The accuracy of calculations was also affected by careless errors in the application of units for the variables. Mixing of values in kJ and Mwatts in calculations was common and the result accepted, however unrealistic the calculated quantity.

The numerical answers are:

(a) (i) 475.4 Mw

(b) 1821.5 kg/s

Q5

Most candidates were able to generate an accurate stoichiometric equation, though often without including nitrogen in the equation. However, some overlooked the presence of oxygen in the fuel while a large number of wrote the molar equation correctly but interpreted it as a mass equation, resulting in a wide variety of answers for parts (a) and (b). In part (b) several candidates who had omitted nitrogen from the chemical equation also forgot to include it when performing the wet exhaust gas analysis. Mixing of mole and mass values in calculations was common, with almost no one showing the units of a calculated result. In part (c) answers tended to reflect sympathy with the environment rather than scientific knowledge. Few candidates offered comparative knowledge of other fuel types.

The numerical answers are:

(a) 8.95

(b)

CO ₂	17.39%
H ₂ O	10.67%
O ₂	2.22%
N ₂	69.72%

Q6

Many answers to this question showed a very poor understanding of the p - v and p - T property relations for pure substances. Only a few of the more common features were correctly identified by most candidates, including the critical point and the saturated liquid and saturated vapour boundaries. Some candidates seemed unaware how to display the difference between expansion and contraction of a substance as the temperature falls with freezing. Also, in part (b) many incorrectly showed a vapour line with pressure falling as the temperature increased towards the critical point. The triple point and the triple point line were placed in a wide range of mostly wrong positions in the diagrams. In a similar way, labelling the solid, liquid and vapour regions in the p - T diagram was often incorrect.

Q7

Many candidates incorrectly assumed that the pressures in the fluid jet at the beginning and end of the curved vane were different from each other and different from the surrounding atmospheric pressure, suggesting a poor understanding of pressure in a free jet of fluid. Most of these candidates further assumed incorrectly that the Bernoulli equation could be applied to the flow, and this was used to calculate an apparent pressure change in the jet. Also, in many cases candidates assumed that the different jet velocities at entry and exit of the vane reflected different mass flows, violating the continuity equation for the flow. In fact it is frictional losses in the jet caused by contact with the vane that reduces the velocity between entry and exit, causing the jet to enlarge in cross-sectional area to satisfy the continuity equation. Many candidates could not set-up the momentum equations for the flow in the x - and y -directions. Only a few candidates did so successfully and were able to calculate the force components of the vane acting on the water jet. However, very few of these then identified the force of the jet on the vane using Newton's third law of motion. Instead, they simply reported the vane force acting on the jet. Candidates should be encouraged to clearly illustrate and describe the forces used in their analysis and the reaction forces which result so that there is no ambiguity of interpretation.

The numerical answers are:

1624.7 N, acting at 58.6° in the negative y-direction.

Q8

(a) Many candidates ignored the “non-flow” information given in the question and used the steady state, steady flow energy equation to describe the expansion. This incorrectly equates the work done to a change in enthalpy rather than internal energy as the question required. Some candidates also ignored the isentropic conditions stated and calculated a heat transfer quantity for the process. Many appeared unaware that internal energy values are listed in the steam tables. Instead, they deduced values for u from enthalpy values and the enthalpy relation ($h=u+pv$) while in other cases the perfect gas equations were incorrectly used with property values for air. Candidates that used the steam tables often made errors by reading the wrong table entries and producing alarming variations in interpolation and often extrapolation calculations. Here again, as in Q4, values of dryness fraction (quality) $x > 1.0$ were used instead of interpolating entries in the superheat tables. In part (c) of the question, candidates suggested a wide range of often superficial reasons for the differences in work done. Only very few correctly identified the closeness to the saturated vapour boundary and the distortion this produces in the constant temperature p-v curves as the main reason for the difference.

The numerical answers for (b) are:

(a) *412.3 kJ/kg*

(b) *1.293, 411.7 kJ/kg*

SUBJECT C107 – ELECTRICAL AND ELECTRONIC ENGINEERING

General comments:

The rubric on the front cover of the examination books call for candidates to list the numbers of the questions attempted. Many candidates did not do this.

Many of the common mistakes could have been avoided if the candidates had drawn the relevant waveforms or circuit or phasor diagrams. They should be encouraged to make more use of this way of visualising a problem.

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 used JK flip-flops in the counter circuit. The divide-by-three counter is not a maximum-length counter and the unused state can be used as a ‘don’t care’ condition in the truth tables for D_0 and D_1 . Candidates who did not apply this to minimise

their solution were only penalised by the extra time required for designing their more complicated circuit.

Q2

Many candidates did not understand that if the voltage changes instantaneously this means that dv/dt is infinite. From the equation this means infinite current is required which is clearly impossible. Understanding that the capacitor voltage cannot change instantaneously is the key to solving transient problems such as that in part (c).

In part (b) many candidates correctly derived the tangent properties but then did not use them as an aid to quickly and accurately sketching the voltage graph.

Q3

This question on frequency modulation uses what is arguably the simplest modulating signal. Too many candidates seem convinced that the modulating signal has to be a sinusoid.

In part (a) candidates often gave a verbal description which did not make sense and did not mention rate of change of phase. However in part (b) the derivative expression was then given correctly but not applied to the triangular waveform.

Since the carrier frequency (2 MHz) is much greater than the signal frequency (500 Hz) the power is the same as that of the unmodulated carrier.

Numerical answers:

mean power in a 1Ω resistor = 12.5 W,

frequency deviation = 318 Hz.

Q4

A common mistake in part (b) was to miss the fact that the 5Ω resistor is shorted by the 2 V source when calculating the Thevenin resistance. Many candidates ignored the hint to apply Thevenin's theorem. Thevenin can be applied to the 5 V, 3 and 2Ω loop giving the solution very easily. The commonest method used was to apply Kirchoff's laws to solve the circuit. Many candidates then made mistakes in the resulting equations.

Part (c) tested the understanding of Thevenin's theorem directly. No electrical measurements can distinguish between the two circuits. Measuring the temperature difference is the only way since the Thevenin circuit will always have less power dissipation for the same terminating conditions.

Numerical answers:

power in the 1Ω resistor = 1 W.

Q5

Parts (a) and (b) were done correctly by many candidates. Difficulty with the expressions for R and C in series and parallel caused a few candidates problems.

Numerical answers:

$n = 2$

Q6

This question was about rectified waveforms and properties such as mean and peak values. Few candidates answered the question fully. Most candidates did not sketch the voltage and current waveforms for either part (a) or part (b). In general it is always a good idea to draw waveforms. In this case the simple area evaluations needed for the calculation of the mean value become obvious.

In part (b) it is important to justify the assumption that the voltages at the inputs of the operational amplifier are equal by stating that the amplifier has infinite gain and there is negative feedback.

Numerical answers:

mean current = 35.6 mA,

$R = \text{peak voltage/peak current} = (1 \times \sqrt{2} \text{ V}) / (\pi/2 \text{ mA}) = 0.9 \text{ k}\Omega$

Q7

Many candidates correctly calculated the value of the collector resistor. However only a few were able to calculate the small-signal voltage gain. A common mistake was to include the 20 k Ω resistor in the input impedance calculation.

Numerical answers:

$R_C = 5 \text{ k}\Omega$, $A_V = -200$, $r_{\text{out}} = 5 \text{ k}\Omega$, $r_{\text{in}} = 5 \text{ k}\Omega$

Q8

In part (a) most candidates correctly calculated the line-to-neutral voltage and the load currents. However many then simply added the magnitudes of these currents when calculating the neutral current. A phasor diagram would have made the solution clear.

Numerical answers:

$I_R = 1.15 \text{ A}$, $I_Y = 1.92 \text{ A}$, $I_B = 0.72 \text{ A}$. $|I_N| = 1.05 \text{ A}$.

$I_L = 17.9 \text{ A}$, $I_P = 10.3 \text{ A}$

SUBJECT C108 – SOFTWARE AND INFORMATION SYSTEMS ENGINEERING**Comments on Individual Questions:****Q1**

Software Design.

This question contributed to the assessment of learning outcomes i and ii. The question relates mainly to the part of the syllabus on “analysis and design (including architectural design and design patterns).”

There were a few good answers to this question, most of which followed the treatment of design in the book by Pressman, who discusses data design, architectural design, interface design and component-level design.

A large number of students interpreted the question as one about software development as a whole. This was surprising because this meant that they gave answers in which software design was explicitly named and discussed as a topic, but only as a small part

of an answer in which as much space was devoted to each of requirements elicitation, analysis, testing and implementation as to design.

Q2

Functional Requirements.

This question contributed to the assessment of learning outcomes (i), (ii) and (iii). The question relates mainly to the part of the syllabus on “requirements elicitation/specification” and on “system models.”

Most students could state what is meant by the functional requirements of a system, though many, when illustrating their answer, gave as examples non-functional requirements such as efficiency. In the second part of the question many students argued that changing requirements are one contributor to the difficulty of providing a complete and consistent statement of the functional requirements. A few recognised that the diversity of stakeholders in the system typically result in conflicting requirements that must somehow be resolved.

Only a handful of students attempted the third part of the question, with the result that the overall performance in the question was poor. This was disappointing, given that the recommended texts for the unit provide good coverage of the topic. Pont gives an extensive treatment of data flow diagrams in his discussion of requirements analysis in process-oriented development (though does not seem to use the term, “functional requirements”). Pressman, in describing analysis modeling, also focuses on data flow diagrams as a way of modeling the functional domain. Pressman, Sommerville, and Booch et al. all explain how, in object-oriented analysis, the modeling of functional requirements can be done using scenarios and use case diagrams.

Q3

Programming Paradigms.

This question contributed to the assessment of learning outcome (i) and indirectly to the assessment of outcome (iii). It relates mainly to the part of the syllabus on “programming paradigms” but is also relevant to “development paradigms,” “analysis and design,” and “implementation.”

There were a handful of very good answers to the second part of the question, on object-oriented programming. Most students who attempted the question were able to state the main principles of this paradigm even if most were unable to address how object-oriented programming languages such as Java or C++ provide direct support for these principles.

The first part of the question, on structured programming, was attempted by only a few students, and was not well done. It appears that in covering the “programming paradigms” topic in the syllabus, students have concentrated on object-orientation and have neglected other paradigms.

The most extensive treatment of structured programming in the course texts is given by Pressman in his discussion of “component-level design.”

Students were expected to note that the idea in structured programming is that any program can and should be constructed using only a small set of logical control constructs or structures. Three constructs are identified: sequence, selection and iteration. Within a sequence, actions are performed sequentially, one after another, in the order they appear in the text of the program. A selection provides for a choice of actions, based on a condition, and iteration provides for the repeated performance of an action which continues until some condition is met. The structures have in common that the control path through them enters at the top (one entry point only) and exits at the bottom (one exit point only). Structures can be nested, so that a selection, for example, may represent a choice between two sequences. Nesting is central to the approach, and in program development is shown by appropriate use of indentation. Structured programming is sometimes referred to as “goto-less” programming.

Q4

Prototyping.

This question contributed to the assessment of learning outcomes (i) and (ii). It relates mainly to the part of the syllabus on “prototyping and evolution” but is also relevant to “development paradigms,” “project management,” and “software process models.”

This was the most popular question in the examination, and the best done, with a few students obtaining full marks. Most, though not all, students appreciated the difference between throw-away prototyping and evolutionary prototyping and could give examples of advantages that prototyping has over more traditional development methods. Discussion of disadvantages was more mixed. For evolutionary approaches these include that managing prototyping projects is more difficult than more traditional approaches. The absence of a requirements specification makes it impossible to verify the system against requirements, and the absence of a well defined sequence of deliverables means that effective management requires previous experience of prototyping projects.

Q5

Project Management and Software Metrics.

This question contributed to the assessment of outcomes (iv) and (ii). It relates mainly to the parts of the syllabus on “project management,” “quality assurance and management,” and “software measurement and metrics.”

This question was comparatively well done, particularly the first part where many students were able to give quite extensive discussion of alternative team structures for software projects. The last part of the question, on software metrics, was more mixed. A number of students could name one or more software metrics but appeared to be unable to discuss their use.

Q6

Software Design and Dependable Computer Systems.

This question contributed to the assessment of outcomes (i), (ii) and, indirectly, (iii). It relates mainly to the parts of the syllabus on “... design,” “development paradigms,” “software dependability,” and “implementation.”

Part (a), on modularity in software design, was reasonably done, with most students able to state what a module was and what the advantages of modularity are. Answers were mixed on contrasting the kinds of modules obtained in functionally decomposed systems with those obtained in object-oriented approaches, but most students could make relevant points here.

Parts (b) and (c), relating to dependable computing, were attempted by fewer students, and in particular the last part, which asked for a discussion of how error handling might be approached in a programming language of the student's choice, was attempted by only a handful of students. Nearly all of these students chose keyboard input validation as their example. These answers were rewarded, but it was disappointing that students appeared unaware of the facility for exception handling in languages such as C++, Ada or Java. The reader is referred to the treatment in Pont (who has a reasonable section on error handling in C++) and in Sommerville (who uses Java as the example language when discussing error tolerance).

Q7

Software Testing.

This question contributed to the assessment of outcomes (i), (ii) and (iv). It relates mainly to the parts of the syllabus on "testing," "assessment and evaluation," "verification," and "project management."

Students generally did well on this question. They were generally familiar with the idea that software testing is intended to uncover errors in the system, and that a good test is one which uncovers an error. A number of students contrasted this objective, for "defect testing", with that of "validation testing" used in acceptance testing for the client. It was encouraging that many students could make reasonable comments on what features of a software system make it easier (or harder) to test.

The last part of the question, on criteria that might be used to decide when testing should stop, was not well done, however. Many students stated that testing stops when there are no more errors left to find. A handful of answers did appreciate, however, the diminishing returns of testing, and that if testing is effective the number of errors detected per unit time of testing should decline as testing continues. Testing as a process can be thought of as a form of selection, in which errors which occur only rarely, under an unusual combination of circumstances, have a competitive advantage over other defects. No practical testing strategy for a complex system can realistically detect and eliminate all of these. So in planning the testing strategy some threshold should be set which denotes the point at which it is judged that the uncovering of further errors through continued testing no longer justifies the time and effort expended on it. The setting of this threshold will depend on a number of factors including the type of application and the consequences of system failures. Verification and validation activities in addition to testing should be employed, especially for safety critical systems, to increase confidence in the dependability of the final product (cf. part (b) of the previous question).

Q8**Configuration Management.**

This question contributed to the assessment of outcomes (iv), (i) and (ii). It relates mainly to the part of the syllabus on “configuration management.”

Students generally struggled with this question, with over a third of students omitting it completely, and only a few of those who did attempt it obtaining more than one or two marks. There were a few good answers but the majority of students who did attempt the question produced answers which indicated that they had not met the concept of configuration management, but discussed project management instead.

For the first part of the question a brief answer was expected noting that configuration management is part of the quality management process concerned with “the development and application of procedures and standards to manage an evolving software product.” The procedures in question relate to dealing with system changes (recording them, tracking them and relating them to different versions of the software). The second and third parts of the question were looking for a basic appreciation of why configuration management is important, and of the kinds of procedures used in managing software change. The reader is referred to the books by Pressman and Sommerville both of which include a chapter on configuration management.