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 2002 – PART 1/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
CERTIFICATE UK									
C101	Nil								
C102	Nil								
C103	1				1				100.0
C104	1			1					100.0
C105	Nil								
C106	Nil								
C107	1						1		0.0
C108	1			1					100.0
O'SEAS									
C101	511	3	17	45	127	28	291	31.2	37.6
C102	428	5	12	51	98	30	232	32.9	38.8
C103	498	2	19	67	95	40	275	31.6	36.7
C104	448	1	18	80	171	27	151	39.6	60.3
C105	396	1	17	45	104	15	214	33.4	42.2
C106	274	8	30	32	59	19	126	37.1	47.1
C107	268	1	1	15	57	18	176	27.8	27.6
C108	55	1	2	7	16	7	21	36.5	47.3

SUBJECT C101 – MATHEMATICS

Comments on Individual Questions:

Q1
The most common response to this question was no attempt. The few marks that *were* gained for this question were overwhelmingly for the first part (sketching the graph) – but most students resorted to calculating the co-ordinates of a few points in order to determine the shape of the graph. Candidates were clearly expecting a question on parametric differentiation and a few of them answered the set question by finding derivatives rather than integrals. Less than 5% of attempts made any progress in the direction of the given answers for parts (ii) and (iii). Part (iii) was found by the candidates to be particularly difficult, perhaps because it was not completely standard.

Q2
The first part of this question was done reasonably well, although some students interpreted the 'first-principles' in the question to refer to the differentiation needed to find the derivatives used to calculate the coefficients in the Maclaurin series. In part (b), (i) was generally answered well whilst (ii) was less well tackled. Some students used the series derived in part (i). However this does not establish the required result; rather, it simply shows that the first two terms in the series for the LHS and RHS are the same.

Q3
This was a fair question which exposed the fact that many students do not fully understand the behaviour of the sine and cosine functions. The potential link between the parts was not spotted by many of the candidates. The wording of the question led to too wide an interpretation of what would be a satisfactory form for the answers.

Q4
A large number of students attempted to solve the equation in general and then inserted the two specific options for E (from parts (i) and (ii)) into the general form of the solution they had obtained. Unfortunately, in obtaining the general solution they had implicitly assumed that E was constant so their general solution was correct for part (i) but not for part (ii). Many students made reasonable attempts at part (i) using separation of variables but did not rearrange their solution to give i explicitly. The integration by parts required in solving part (ii) was generally reasonably done in principle but poorly done in detail – the algebra of the process causing a number of problems particularly regarding the factor R/L. The factor L/R is the time constant of the circuit, which candidates should have realised, and a relatively simple substitution would have saved much algebra.

Q5
On the whole those who knew how to proceed made good progress with the question. A significant minority answered part (i) where w is real by taking the real part of w to be zero and similarly in part (ii) where w is imaginary they took the imaginary part to be zero. Very few students answered part (iii) satisfactorily in terms of one point being a pole and the other a zero of the transformation; the knowledge of poles (and zeros) was beyond the students' ken.

Q6

There was a variety of correct approaches to the solution. A few students quoted (and used correctly) a theorem which many UK engineering undergraduates would not have encountered but which is applicable here. This made part (i) straightforward. Some of these candidates also quoted a corollary of this theorem which covered part (ii): however this corollary was usually misquoted in a way which still allowed the result to be obtained. The most common approach was simply to start with the given function u(x,y) and carry out a number of differentiations using the quotient rule. In many cases candidates did obtain the required results relatively quickly but there were a number of 'solutions' which took several pages of algebra before claiming (usually inaccurately) to have established the required result. A reasonable number of students undertook some rearrangement before proceeding to use implicit differentiation to establish the results. This made the algebra easier provided that the implicit differentiation was handled correctly.

Q7

Part (i) was very poorly done. The overwhelming majority of attempts did not have any systematic approach. Candidates simply wrote down a set of vector relationships from the diagram, which in many cases were correct, but these were not helpful in terms of answering the question. This appears to be a continuing weakness which candidates need to address. There were more correct answers to finding the scalar triple product in part (ii), although there were also a large number of meaningless definitions of the triple product (mixing vectors and scalars in the same product). This was probably the second least attempted question (behind Q1).

Q8

A fair question which most candidates attempted and began in the correct way. However, algebraic mistakes were legion and the number obtaining the correct characteristic equation was small. Many candidates determined that the eigenvector corresponding to the zero eigenvalue was (0,0,0) which shows a fundamental lack of knowledge and understanding.

Q9

Although the mathematical techniques being tested are not difficult the complexity of the function involved led to large numbers of calculational errors which prevented students from gaining marks even though they probably understood the principles of continuity and knew the formula for Newton's method.

Q10

The three probability/statistics questions were poorly answered – this question being the one on which, overall, candidates fared best. However, many students did not correctly identify how to calculate the required probability. The one most commonly calculated was P(X=4), but others included such things as 1-P(X=4) and 1-[P(X=1) + P(X=2) + P(X=3)]. It is possible that there may have been language problems for some students as well as mathematical misconceptions. However, part of the skill in probability lies in translating a verbal description of a problem into mathematical terms.

Q11

Many candidates who identified that this was a question about the binomial distribution calculated the wrong probability. Most common was P(X=5) where often X was actually the number of faulty components not the number of ones with no fault. As in Q10 there may have been some misunderstanding of the language.

Q12

This question defeated almost all students although many made an attempt to answer it. The overwhelming majority of attempts did not even endeavour to combine the two given random variables. Amongst the minority who did it was most common to simply add the two to get a new random variable which was the sum of the length of one rod and the overlap. A simple diagram would have given the mean length and far too many failed to do this. No one identified correctly that the variance of the (correct) new random variable should be $2\sigma_1^2+\sigma_2^2$; the few who had the mean as $2\mu_1-\mu_2$ used a similar formula for the variance.

Q13

This was an easy question which was answered well by those who attempted it (although many candidates did not). The final part (deducing a simpler logically equivalent result) was often omitted – too few students simply looked at their truth table to observe that the result was equivalent to A. As a result, much time was wasted on the manipulation of logical expressions.

SUBJECT CI02 – ENGINEERING MATERIALS

Comments on Individual Questions:

Q1

(a) Candidates were required to give a description of the manufacture of a test piece with a gauge length and gripping shoulders. Test equipment was to be briefly described to show how test piece is extended and resulting load monitored. Conversion to a stress-strain output graph. Selection of the maximum in the trace to give ultimate tensile load and its conversion to a UTS via the original cross section area.

(b)(i) The tensile yield load from

Load = yield stress x cross section area

$300 \times 10^{-6} \times \pi \times 5^2 \times (10^{-3})^2$

$= 300 \times \pi \times 25$ N

= 23.56 kN

(ii) Localised necking occurs shortly after the UTS and so

Load = UTS x area

$400 \times 10^{-6} \times 5 \times (10^{-3}) \times \pi$

$= 25 \times \pi \times 400$ N

= 31.4 kN

Q2

(a) Simple descriptions of the transfer of two outer electrons from each Mg atom to each O atom to create ionic attraction are needed. However this alone does not account for the extended bonding required in a crystal. Hence descriptions of the six nearest neighbour positions with identical attractions and some indication of the transient nature of the three dimensional ionic bond are required. This should be described or displayed within an extended three dimensional lattice similar to the classic sodium chloride arrangement.

(b) A description of the primary co-valent bond between C and H atoms by the sharing/pooling of a pair of outer electrons to produce a single bond is required.
The formation of secondary bonds between these electrically neutral molecules, through Van der Waal type forces, is required to produce solid polyethylene.

(c) The concept of the metallic bond with the pooling of the conduction electrons in close-packed lattices is needed. In this case it is an f.c.c. arrangement created by pure aluminium. This pooling can be maintained without any phase change if a new metal is introduced into substitutional positions in the lattice and this is possible at this copper content in this alloy. Many candidates incorrectly described the bonding in an intermetallic compound of $CuAl_2$.

Q3

(a) Silicon is an intrinsic semiconductor above absolute zero, outer electrons of each atom in the bulk are involved in primary bonds with surrounding atoms. Thermal energy may enable an electron to leave these bonds and hop from atom to atom. It is then termed a conduction electron as it contributes to conductivity. At the same time, the hole left behind is filled either by an electron from a neighbouring bond or by recombination with another conduction electron. The hole thus moves or is lost. It is effectively a carrier of positive charge as it is drawn towards regions of negative potential. Hence holes also contribute to conductivity.

In terms of the band model of electron energy states in a solid, the bonding levels (valence band) are separated from the delocalized states (conduction band) by a distinct gap in the near continuum of closely spaced energy levels found within the bands. To change its state an electron must receive enough energy to cross the energy gap (thereby escaping the bond but not the solid) into one of the available empty states.

An extrinsic semi-conductor is produced by having a controlled amount of impurities to provide such charge carrying capacity. Here the impurities are called dopants.

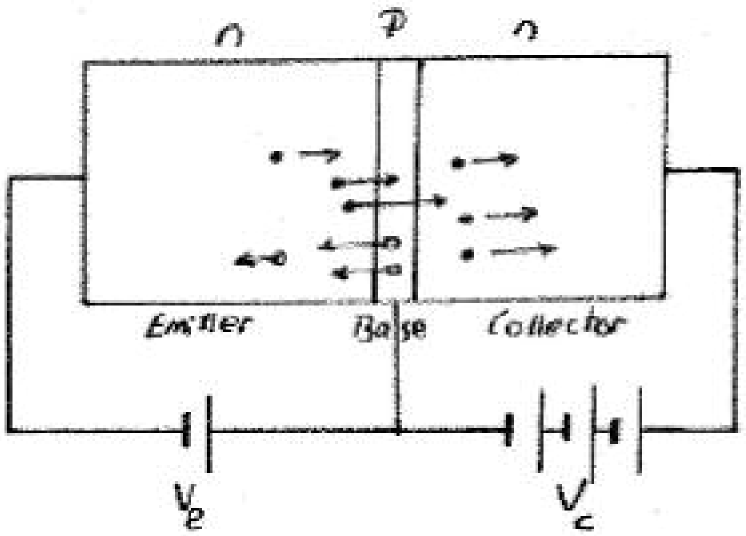
Both n and p type silicon based semiconductors are extrinsic.

In n-type the major charge carriers are extra electrons that are made available by doping with group VA elements notably phosphorus which contain 5 valence electrons.

In p type the major charge carriers are electron holes produced by doping with group IIIA elements, notably aluminium. These elements have 3 valence electrons and create electron holes accordingly as the major charge carriers.

(b) At a pn junction in a semiconductor there is an interface where the spare electrons and holes cancel each other out. This produces a thin insulating layer. However, if a potential difference is applied (forward bias) that matches the charges on the carriers, they may be forced across the interface where they combine with their opposites and current flows. With a reverse bias the charge carriers simply drift within their regions and no charge carriers cross the interface, hence a very small current is observed. The device therefore acts as a rectifying diode allowing large current only in one direction in response to an alternating voltage. In the forward bias condition the recombination of holes and electrons may occur with a release of energy via the emission of a photon. Such a device is thus a light emitting diode. (LED).

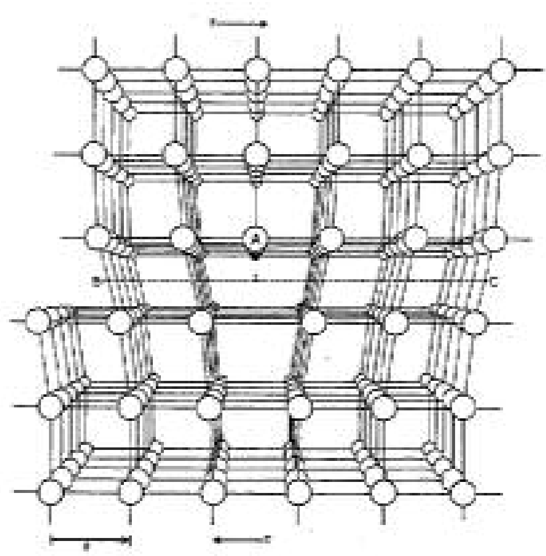
(c) An n-p-n amplifier transistor functions as shown in the diagram below.



The n type emitter material is under forward bias and the applied negative voltage drives electrons to the base. Here they recombine with holes in the p - type base layer and a current flow occurs. However, if the base is thin they can cross into the collector material and add to the electron flow occurring under the forward bias collector voltage without hindrance. It turns out that an exponential relationship exists between the collector current and the emitter voltage. Hence the device effectively amplifies the emitter current.

Q4

(a) A diagram is required similar to that shown below:-



Apart from the slip vector *s* and dislocation line at A, the sketch should show "compression" above the line and "tension" below that give distorted lattice sites accordingly and an indication of how the extra half plane will "ratchet" through the structure. The whole description can be considered to represent a particular slip system in the specimen.

The origin of a small number of dislocations can be associated with imperfections that occur in solidification within grain and at grain boundaries. These glide under applied shear stress and can multiply by Orowan Looping round second phase particles and/or forest dislocations. Dislocations can entangle and create jogged regions that multiply the effective length of the dislocation line. Further loops can be created around loops as more dislocations pass on their relevant slip plane.

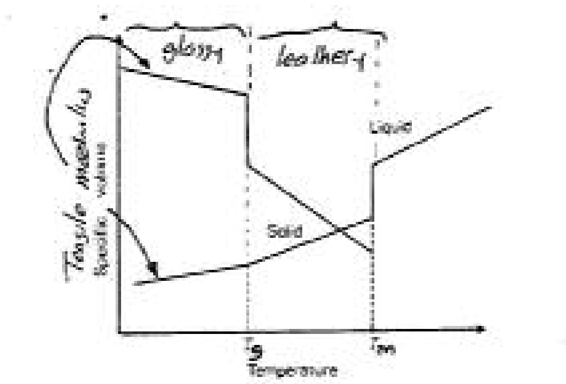
The presence of a few dislocations enables shear to be triggered at lower applied shear stress than if whole planes are sheared. The line defects effectively concentrate the applied shear stress and enable the strain to be propagated in an incremental fashion. Credit was given for diagrams that represented this concept.

As dislocation density increases then elastic strain fields occur around them and similar dislocations increase this strain if they meet. Usually entanglement (but occasionally annihilation) occurs and this causes the array to lock up. An increase in shear stress is needed to cause further plastic strain and therefore work hardening follows. Therefore the bulk flow stress usually increases with increased dislocation density. This phenomenon is behind the observation of work hardening in ductile metallic alloys if the polycrystalline array has sufficient independent slip systems.

Q5

(a) Thermoplastic polymers show reversible viscoelasticity with temperature due to the breaking and remaking of secondary bonds between the polymer chains. Thermosetting materials contain a high level of crosslinks between chains and do not show these reversible effects once polymerised.

(b) + (c)

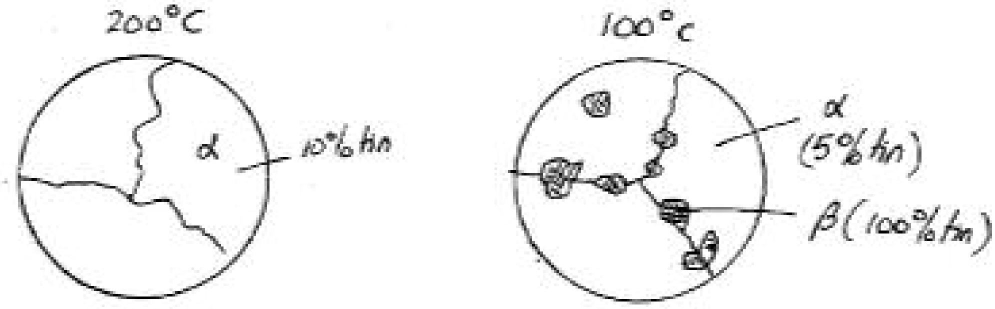


graphical sketch

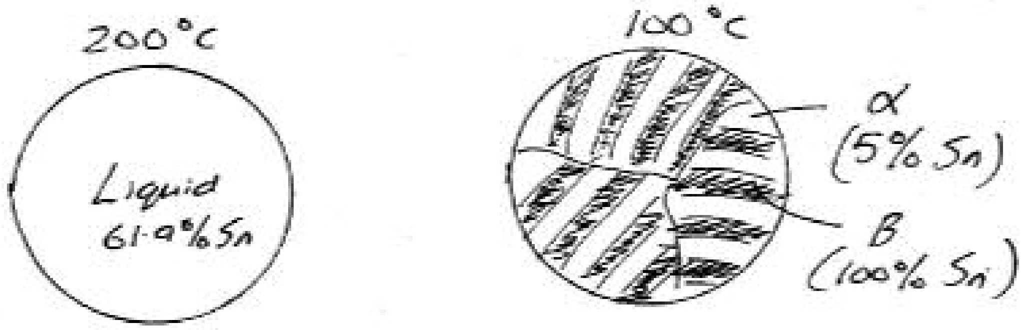
Identification of Tm, Tg, glassy and leathery regions is needed on the graph as shown above.

Q6

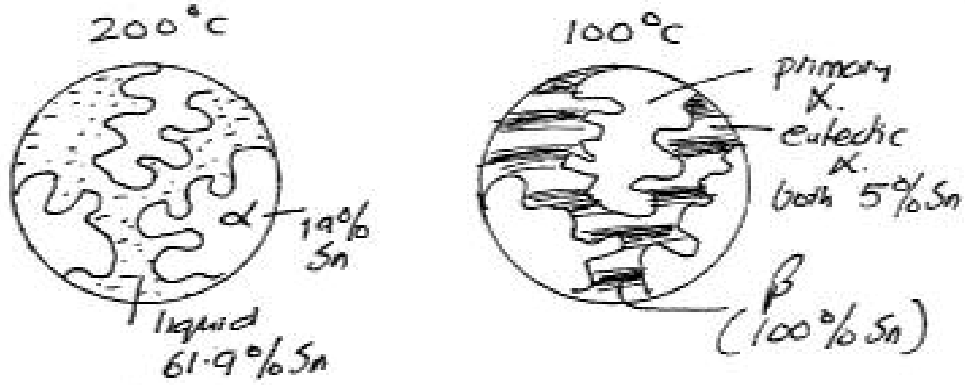
(i) Candidates were required simply to sketch the microstructure schematically as shown below and read off the chemical composition of each phase as shown on the equilibrium diagram. This required the reading of the appropriate phase boundary in two phase regions and the construction of a tie-line at the temperature. The relevant compositions are where this tie-line meets the phase boundary. Candidates were not always aware that in equilibrium conditions single phases (including liquid) have the overall chemical composition with no chemical gradients present.



(ii)



(iii)



In all cases the chemical composition of the tin content is shown which should be balanced by the lead content up to 100% total. Many candidates did not appreciate that the α and β phases can exist as solid solutions of lead and tin.

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 procedure required to derive the equation for circumferential strain required in part (i) of this question. However, some candidates were unable to correctly derive the expression for the hoop stress in the shell. A few candidates derived equations for a cylindrical rather than a spherical shell.

Most candidates were able to substitute the numerical information given in part (ii) of the question into the formula provided in part (i). 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 gauge pressure in the vessel which was 2.5 MN/m^2.

Q2

Most candidates attempted to draw the free body diagram for the upper block in part (i) of this question. Many were unable to place the reaction force between the blocks correctly, but in other respects the diagrams were usually right. Most candidates then took moments about point A and correctly derived the correct expression $\frac{dW}{2x-d}$ for the minimum value of P. Some candidates adopted less direct methods of solution, but generally these were still successful.

Generally those students who had successfully answered part (i) of the question were able to use the same techniques successfully in part (ii) to obtain a minimum value for P of $\frac{2dW}{2x-d}$.

In part (iii), where candidates had answers for parts (i) and (ii), they recognised that as the value in part (i) was less than in part (ii) the mode of collapse would be through the rotation of the top block about point A.

Many of the candidates who successfully reached this part of the question were able to realise that collapse was most likely to occur when the load P was placed at the end of the upper block and hence determined the maximum value for P of $\frac{dW}{L-d}$.

Some candidates assumed alternative incorrect worst scenario locations for P.

Q3

Most candidates drew the three free body diagrams required in part (i) of the question. These were generally correct although many candidates omitted the reaction force between the fixed pulley and its mounting. Some candidates chose to include the inertial forces on their diagrams, but these could only be considered as being correct if all the inertia forces were shown. A number of candidates drew a diagram for the complete system rather than the individual free body diagrams requested.

The usual form of solution to part (ii) of the question required that the equations for linear motion of the suspended mass and for the suspended pulley were determined and also the equations for rotary motion of the two pulleys. Many candidates were able to do this correctly, but a number omitted the moment of inertia terms for the pulleys. It was also necessary to recognise that the suspended pulley will accelerate upwards at half the rate at which the suspended mass accelerates downwards. Some candidates assumed that the accelrations were of equal magnitude. This and various other algebraic errors meant that only a few candidates obtained the completely correct expression of $\frac{(4M-2m)g}{4M+m+5I/{}^{2}}$ for the required acceleration. Many candidates were able to get expressions which were similar but contained incorrect signs. Candidates should be encouraged to consider the implications of their answers. Considering this problem it is clear that the two masses must act in opposition in producing acceleration and the inertia of all the elements must be sum. This consideration would have enabled some candidates to identify incorrect signs.

Q4
Most candidates recognised the circuit used in this question and knew that the voltage across the inductor would vary in some exponential fashion. They were less successful however in determining the exact nature of this variation and frequently sketched voltages which either increased exponentially or decayed to a finite value.

Most candidates were able to determine the time of 0.1386 seconds required in part (ii). Incorrect answers were most frequently due to numerical errors rather than errors in method.

Less than half of candidates correctly determined the final circuit current of 0.6 A required in part (iii). Some candidates determined the current for the situation existing in part (ii) and some considered the conditions when five exponential time periods had passed rather than the final current value.

Q5
Many candidates attempting this question demonstrated that they did not have a clear understanding of impulse loads. In part (i) most candidates recognised that the moment of inertia about point O could be determined using the parallel axis theorem. Few however were able to correctly take into account the effect of the frictional torque which is most simply done through the use of an energy balance equation. The correct expression for the impulse of $\frac{1}{r}\left[(I_G + mr^2)(2T_f\pi + 4mgr)\right]^{0.5}$ was rarely obtained.

Correct answers to part (ii) of the question were also rarely obtained, but credit was given to candidates who adopted appropriate methodology. The initial angular velocity was 11.6 rad/s and the angular velocity after one revolution was 3.86 rad/s.

Q6
Most candidates were able to understand the principle of operation of the thermometer described in this question. They were therefore able to deduce that the pressure inside the spherical container was proportional to the temperature. Most candidates were also able to relate the pressure to the length of the mercury column correctly. Numerical errors were frequently made however so many were unable to obtain the correct length of 0.275m for the mercury column.

The answer to part (ii) of the question could be obtained very easily once it was recognised that the pressure and hence temperature was proportional to $\sin\theta$. The correct expression is simply T=100 sin θ where T is in degrees C. Most candidates took a less direct approach however and therefore frequently failed to obtain the correct answer due to algebraic errors. Candidates should be encouraged to consider the analysis which they intend to undertake and identify that which will most simply provide them with the answer as otherwise they can waste much time in undertaking unnecessary algebraic manipulation.

Q7

Most candidates were able to write down the steady flow energy equation required for this question. Generally candidates were able to determine the outlet enthalpy from the values of internal energy, pressure and density given. Some errors were made though in converting SI units. The correct rate of heat transfer of 208.5MW was usually obtained. The commonest error was due to using incompatible SI units for the kinetic energy and enthalpy terms in the equation. A statement that the potential energy term could be considered to be negligible was required for full marks.

Q8

This question could be made simpler through recognition that the circuit in the figure was symmetric. This meant that the pairs of points A and E and B and D are at the same voltage and hence can be connected together. This reduced the problem from one with five unknown voltages to one with only three unknown voltages. Many candidates did not recognise that the circuit was symmetric and some of those that did failed to use this property to simplify the problem. Where candidates attempted to solve for five unknown voltages it was rare that correct answers were obtained because of the complexity of the algebra involved. Where the symmetry property was exploited most candidates obtained the correct voltages across OA (and OE) of 2.69v, across OB (and OD) of 0.77v and across OC of 0.38v. Some candidates chose to use unknown loop currents rather than voltages to solve the problem. Again, although slightly more complex, this was generally successful where symmetry was recognised, but usually failed otherwise. Some candidates did not appear to recognise that the voltage difference across any part of a passive circuit can not exceed the supply 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 compared with previous examinations, 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, Q4 and Q7.

Comments on Individual Questions:

Q1

The most appropriate missing words are identified as follows

1 form tolerance	2 product design specification (PDS)	3 Laplace
4 simaplex	5 longest path	6 cell
7 word recognition	8 accumulator	9 top-down design
10 structured programming		

Q2

(a) 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, <u>before</u> writing the final text as concisely as possible.

(b) The decision tree is a method that can be used to evaluate different alternatives. Decision trees are often used in evaluating business investment decisions by providing a structured analysis that takes into account the outcome of possible future decisions, including the effect of uncertainty, and allows the benefit of varying levels of present and future profit to be weighed against the concomitant commitments. Decision trees can also be used in the design process to evaluate different design alternatives. After a number of alternative design approaches have been identified, the designer selects the one that appears to offer the optimum solution. This approach is then investigated at a more detailed level, revealing other options that again are evaluated and the best one selected. This process continues to some logical end point that may be a certain critical period of time (e.g., in the case of financial decisions), or to the lowest level of detail in a design decision. This top-down approach is more commonly used in design, but the process can also be started at the lowest level, building up to the overall concept. Although the decision tree is based on selection of the best option at each branch or level of the tree, this does not ensure that the best possible overall concept will be obtained during the first iteration. Decisions made at any particular level may turn out to be less than optimal in the light of information disclosed at subsequent levels. The impact of later decisions on earlier decisions is important in the effective use of decision trees, and thus considerable iteration is necessary. It is important for the decision tree to be regarded as a dynamic device, one in which new (and better) information is integrated as it becomes available.

The construction of a decision tree is a useful technique when decisions must be made in succession into the future.
A decision point in the decision tree is indicated by a square, and circles designate chance events (states of nature) that are outside the control of the decision maker. The length of line between nodes in the decision tree is not scaled with time, although the tree does depict precedence relations.

Relatively few candidates correctly identified the nature of a decision tree. Many simply described the organisational structure of a typical company. A simple sketch was clearly needed in the answer, but was absent in most cases.

(c) A list of the main rules or laws of good report writing is published by the IEE as follows.
A good report is easy to recognise. Its title is precise and informative, its layout and format are well organised, and the binding is easy to handle and opens flat to reveal both text and diagrams. A typical summary of the report writing laws are as follows.

1. The reader is the most important person.
2. Keep the report as short as possible
3. Organise for the convenience of the report user.
4. All references should be correct in all details.
5. The writing should be accurate, concise and unobtrusive.
6. The right diagram with the right labels should be in the right place for the reader.
7. Summaries give the whole picture, in miniature.
8. Reports should be checked for technical errors, typing errors and inconsistency.
9. The report should look as good as it is.
10. The reader is the most important person.

The first law is repeated because it is the only law which should never be broken.
Flexibility and adaptation may be usefUl, but only to make the report more accessible to the reader.
All other considerations, even saving time and money, are in the end counter-productive if readers find reading the report a burden they would prefer not to undertake.

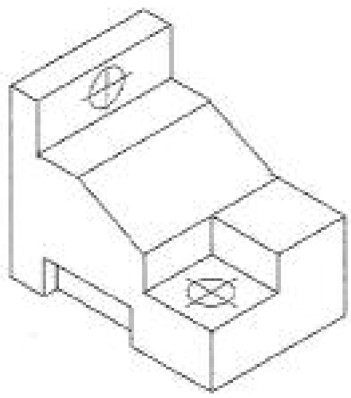
A significant number of candidates had clearly studied the IEE publication, although many ignored the instruction to "list" the main rules in a form similar to the above.

Regarding the whole of Q2, candidates should be strongly advised to read the instructions very carefully for this type of written question, otherwise a lot of examination time is simply wasted. Even though the question requested the use of sketches and diagrams, these were usually either omitted or of poor quality.

Q3

(a) (i) These are the maximum and minimum surface roughness values (machining is not prohibited)
(ii) A polarised capacitor
(iii) A double acting hydraulic cylinder with a single piston rod

(b) Isometric view as follows



There were a significant number of candidates who ignored the instruction to produce an <u>isometric sketch</u>.
The main problems involved the geometry associated with the hole on the horizontal surface. Sometimes the preliminary sketches were omitted even though the question clearly requested these.

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 _ 4 _ 5 _ 8 _ 9**, and the estimated completion time is **35 weeks**.

Q5

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 rather simple 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.

Q6
(a)

Cumulative PW Calculations

	(A)	(B)	(C)	(D)
		Present Worth	Cumulative PW at	Cumulative PW at
End of	Nominal	of Cash Flow	i = 20% through	i = 0% through
Year k	Cash Flow	at i = 20%	Year k	Year k
0	-£25,000	-£25,000	-£25,000	-£25,000
1	8,000	6,667	-18,333	-17,000
2	8,000	5,556	-12,777	-9,000
3	8,000	4,630	-8,147	-1,000
4	8,000	3,858	-4,289	7,000
5	13,000	5,223	934	20,000

Total PW = PW of cash receipts - PW of cash outlays

Total PW = £8,000 (P/A, 20%, 5) + £5,000 (P/F, 20%, 5) - £25,000 = **+ £934.29**

Because PW> 0, this equipment is therefore economically justified for the MARR of 20%

The cash flow diagram was rarely drawn correctly. The most common mistake was to ignore the negative initial outlay of £25000. Many candidates also ignored the time value of money (resulting in column C above) and simply used the nominal values (effectively resulting in column D above).

(b)

Hours Late	Probability %	Probability	Cumulative	R.N. range	Col (2) R.N.	Hours/sim.
0	40	0.40	0.40	1 – 40	17,2	2 x 0 = 0
1	25	0.25	0.65	41 – 65	41,52	2 x 1 = 2
2	20	0.20	0.85	66 – 85	69,72,85	3 x 2 = 6
3	10	0.10	0.95	86 – 95	92,93	2 x 3 = 6
4	5	0.05	1.00	96 – 100	97	1 x 4 = 4

total = 18 hours

total for 10 simulations = 18 hours , so average hours late = 1.8 hours

This section (b) was very poorly attempted, indicating a major failure to understand the use of random numbers in a simple simulation exercise.

Q7
The approximate value from the graph using the 'odd' values as the appropriate cell width gives the following estimate
Distance = 2 [2.2 + 8.2 + 13.5 + 17.2 + 19.1 + 18.1 + 14.4 +11.4 +10.6 +11.3] = 2[126] 252 m
From Simpson's rule Distance 1/3{0 + 12 + 4(sum odd = 126) + 2(sum even = 119.6)} = 1/3{763.2} = 251.733 m
ie the difference is less than 1%

Often the approximate value was considerably in error, even though a correctly drawn graph had been constructed. A significant number of candidates failed

to use a proper numerical method such as Simpsons rule or Trapezoidal integration. A few even attempted to use forward and backward difference methods revealing a complete lack of understanding.

SUBJECT C105 – MECHANICAL AND STRUCTURAL ENGINEERING

General Comments:

This year's Paper contained seven questions as opposed to the eight questions of previous years. This was aimed at producing a slightly less demanding Exam workload while still covering adequately the syllabus content. Initial results indicate that there was an overall improvement in performance compared to last year that may be partly attributed to this factor. There was a significant reduction from last year in the number of candidates who were clearly less well prepared for the Exam. There is still evidence that many candidates show a serious lack of understanding of basic principles.

- A total of 396 candidates presented themselves at 9 (overseas) Centres – a decrease of about 6% on last year's number. Performances of candidates varied widely from Centre to Centre with 4 Centres achieving a pass rate of 10% or less; 2 achieving a pass rate of between 20 and 30%; 1 a pass rate of 40%; 1 (the largest Centre which accounted for 86% of all candidates) a pass rate of 45%; and 1 a pass rate of 100%.

- Individual candidate performance varied hugely from a minimum mark of 0% to a maximum mark of 84%. The overall pass rate was 42% compared to 35.6% for last year.

- I believe that the Exam Paper fairly tested knowledge and understanding of the syllabus. Candidates still tended to favour the statics questions (Q1-Q4) rather than the dynamics questions (Q5-Q7) in terms of questions attempted.

- 18.9% of all candidates achieved a mark of less than 20% which was a significant improvement on last year's performance (25%) It is hoped that this is due in some part to better attention being given to self-assessment and preparation.

- There are still some serious examples of candidates showing poor exam strategy and time management, and tutors should note that candidates still require to be given advice and guidance on exam strategy.

Comments on Individual Questions:

The following comments relate to the particular features and concepts which each question is attempting to highlight. In many instances, the numerical answers are of little consequence. What is being looked for is a clear indication that fundamental principles are understood.
Tutors and 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
The majority of candidates still fail to recognise this as a **statically indeterminate problem in tension/compression.** When the assembly is heated, the alloy tube wishes to expand thermally by a greater amount than the steel tube. The steel tube prevents this from happening but is itself extended by a greater amount than it freely desires. For the condition of equilibrium that results, the compressive force in the

alloy clearly must equal the tensile force in the steel. The *strain* in each element is *not* the 'free' thermal expansion (L.α.t) as most assumed. The sum of the actual extension of the steel and the actual compression of the alloy equals the difference in the 'free' thermal expansions. From these two relationships, the force induced in both the alloy and the steel is 21.32 kN. Hence the resulting stress in the alloy is 24.7 MN/m² (comp) while the stress in the steel is 70.7 MN/m² (tens)

Q2
Assesses understanding of **equilibrium and free-body diagrams** and was generally well-done. For pinned frames $\Sigma F_H = 0$, $\Sigma F_V = 0$ and also $\Sigma M = 0$. It should be obvious from observation that the reaction at A can only be vertical and therefore the horizontal reaction at B is 5 kN. From moments about B, the vertical reaction at A is 20kN (upwards) and hence the vertical reaction at B is 10 kN (downwards). Also from observation of the joint D, since there is no other horizontal force present, the force in member CD must be zero. The force in member AC is clearly equal and opposite to the vertical reaction at A (ie 20 kN tensile). The force in BC is consequently 7.07 kN (comp) and that in BD is 5 kN (comp). It is extremely difficult to extend the solution of this question to beyond two pages, yet many did so by not making the simple observations stated above. Candidates need to sharpen up on obvious conditions of equilibrium.

Q3
Assesses the fundamental concepts of **stress-at-a-point** that appears to have shown little improvement in understanding since last year. The maximum bending stress arising from the bending moment acting alone is 120.7 MN/m². The torque from the power transmission is 59.7 kNm that results in a maximum shear stress of 90 MN/m² due to the torque alone. Most candidates got this far then foundered on the evaluation of the principal stresses due to the combined loading. The evaluation of principal stresses is always best done using a free-hand sketch of the Mohr circle which automatically provides the principal stress values.(avoid trying to memorise these formulae at all costs!) Here, the principal stresses are 168.7 MN/m²(tens) and 48 MN/m² (comp) [or vice versa] The principal strains are 916 and -493 microstrain units respectively

Q4
Assesses understanding of **shear force and bending moment distributions** and their relationships, along with an awareness of **static indeterminacy in bending**. Since the beam has an unknown reaction and unknown fixing moment in the 'wall', along with an unknown reaction at its free end, the beam is statically indeterminate (ie more unknowns than there are equations of static equilibrium – part (a)).The question makes no request to establish the values of these reactions – so don't try! Simply indicate what the SF and BM diagrams would look like for some (unknown) forces at the supports and make free-hand sketches accordingly. Bear in mind that you need to show that *your* BMD is correctly related to *your* SFD eg points of zero shear correspond to turning points on the BMD and so on

Q5
Assesses the concepts of **work, energy and inertia**. Credit was given for any reasonable assumptions regarding transfer of energy. The electric power consumption if losses are neglected is simply the product of torque and angular speed and equals 25.1 kW. This may then be converted into a force x velocity statement for the container which establishes the velocity of the container at power switch-off as 2.56 m/s. The KE of the container (3.28 kNm) and of the motor & drum (2.22kNm) at full speed can be established. If, say, this is all converted into 'potential' energy to lift the container, then the distance risen will be 0.56m

Q6

This question required the assessment of the **SHM of a spring mass system** and only part (a) was well understood. It is easier in all these relatively simple cases to reduce the system to a single spring-mass system for which the frequency is expressed as $(1/2\pi)\sqrt{k/m}$. For (a) the frequency is 1.74 Hz. For (b) if the deflection at the end of a cantilever is given, then the stiffness at the end of the cantilever is W/δ ie 1041.7 N/m in this case. Hence the frequency with the given end load is 1.33 Hz. For (c), the spring and cantilever are connected in series (ie same load) for which the equivalent stiffness is 659.8 N/m and the resulting frequency is 1.06 Hz. For (d), the spring and cantilever are connected in parallel (ie same deflection) for which the equivalent stiffness is 2841.7 N/m and the resulting frequency is 2.19 Hz

Q7

This question tested fundamental understanding of **velocity and acceleration characteristics of a simple mechanism** and was generally poorly done. Part (a) simply required the measurement of the given velocity vectors for AB and BC and converting to angular velocities, which were 10 rad/s and 15 rad/s respectively. Some tried to analyse the accelerations by using tensor notation, with very limited success. By far the easiest method, as was suggested, is to illustrate the acceleration vectors. Many candidates simply were unable to do this although a large proportion were able to calculate the centripetal accelerations for the mechanism. The centripetal accelerations of A, B and B with respect to A are 5, 18 and 13m/s² respectively. In addition, A has a tangential acceleration of 2 m/s². The unknown accelerations are thus the tangential components of B, and B relative to A. The acceleration diagram can be readily obtained by constructing from the point O' as directed – the cent. acceleration of A + tan. acceleration of A (to find point a'); the cent. accelerations of both B and B relative to A and hence determining the point b' from the intersections of the (normal) tangential accelerations of these two components. The angular acceleration of BC is then its tan. acceleration divided by its length and equals 120 rad/s². Tutors and candidates are strongly advised to improve skills in visual presentation in this area by vector construction to demonstrate clear understanding of the principles. Purely numerical analyses would naturally be the preferred option in design applications, but not at a level 1 assessment stage.

SUBJECT C106 – THERMODYNAMIC, FLUID AND PROCESS ENGINEERING

General Comments:

The paper was straightforward and followed the same format as in previous years. The majority of the candidates were from one Centre and it is very gratifying to report a substantial increase in the standard of work from this Centre. Consequently there is a corresponding increase in the percentage of candidates passing the examination, to a value which is much more acceptable than that of recent years.

The sign convention for work and heat transfers that we use now, is almost universally accepted. A few candidates used the old convention and most of these wrote a short note on the script explaining that they intended to do so. These were given full credit for their work.

Many of the poor examination techniques mentioned in last year's report still persist. The crossing out of work without anything to replace it still occurs. Lengthy proofs which have not been asked for, gain the candidate no marks and waste valuable time. Candidates often leave a question and return to it later in the answer book without giving any indication of what they have done.

Candidates are mostly aware of the helpful formulae given with the examination paper. However one time saving point should be noted. A reversible polytropic process for a perfect gas is frequently involved. Usually the most useful property to find is a final temperature. Numerous candidates in this examination found it by first determining volumes and then using perfect gas relations to find the temperature. However, the temperature, volume and pressure ratios are given in the data section of the examination paper and these can be used directly, saving much time and effort.

Comments on Individual Questions:

Q1

This question involved finding the work done for a perfect gas in both an isentropic expansion and an isothermal expansion, given the same initial conditions and the same pressure ratio. For the isentropic expansion Q = 0, so:

$$W = (u_2 - u_1) = C_v(T_2 - T_1)$$

The majority of candidates launched into a lengthy derivation to find $W = \Phi(p,v)$. This was quite unnecessary. Very few were able to draw the p~v diagram properly which explained the lack of understanding of the problem.

Q2

The question involved an isentropic expansion and the application of the steady flow energy equation to a nozzle and a throttling process. The important property to find was the final temperature. Much time was wasted by many candidates who failed to use the given pressure ratio ~ temperature ratio relationship. Very few pointed out that the temperature was constant in the throttling process although most used this fact. However, most of the errors involved the failure to use consistent units when applying the steady flow energy equation. Many candidates were unable to draw the full T ~ s diagram.

Q3
This question was done very well. It enabled candidates to demonstrate their understanding of the properties of a pure substance. A common error was to draw the isotherms on the p~v diagram incorrectly. Very few succeeded in finding the entropy of ammonia from the tables.

Q4
The proof of the entropy relationships was generally well done. Candidates should realise that they are unlikely to be asked to prove such a relation without it being of use later in the question. Many failed to take the hint. In part (a) it was necessary to find the outlet velocity from the section. Very few realised that the application of the continuity equation would produce the result required.

Q5
At last candidates sitting this examination showed that they were able to deal with a combustion problem. It was very pleasing that most succeeded in the first part of finding the stoichiometric air/fuel ratio. However, the second part was poorly done, most solutions disappearing into a dense and complex calculation.

Q6
The steam power cycle was a standard question that all candidates should have known how to tackle. Most did well but too many did not have a good physical understanding of the processes involved.

Q7
This question was an example of where a good diagram and clear explanation was essential. Explaining how to find the hydrostatic forces on the gate and stating where they acted was important both for the candidates own understanding and for demonstrating to the examiner that he or she knew the physics of the problem.
Generally the question was well done.

Q8
This question was poorly answered. Solutions tended not to be set out in a logical progression of steps, i.e. velocity shear stress from Newton's law (given) - force torque power. Because of this, simple and avoidable errors were made.

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.

Once again the results are not very good and this is especially disappointing because the questions, being designed to test knowledge of basic principles and the candidates ability to apply them, are kept as straightforward as is possible.

Comments on Individual Questions:

Q1

In part (c) many candidates did not establish how many flip-flops are needed for the divide-by-three counter. Some gave an asynchronous solution. Full marks were given to valid circuits even if not minimised. Some candidates used invertors to realise $\overline{Q_1}$. If full use was made of 'don't care' conditions then the minimisation could be done by inspection. Minimisation was worthwhile since the result is a simpler circuit to draw.

Solution: $J_1 = Q_0$ $K_1 = 1$ $J_{0-} = \overline{Q_1}$ $K_0 = 1$

Q2

The derivation in part (a) was well done and most candidates were able to sketch the exponential decay of the capacitor voltage. However few could sketch the capacitor being discharged by the constant current source! Very few estimated when the straight line diverged appreciably from the exponential.

In part (c) some candidates attempted to use a formula. The point of the question is to apply the results of part (b), particularly the simple constant current discharge model.

Solution: $I = 1$ V/R For $t \leq \tau/5$ the curves differ by less than 2%.
$C > 200$ µF e.g. use 220 µF.

Q3

Few candidates could define instantaneous frequency even though many were able to derive the expression for the instantaneous frequency in part (b).

Solution: r.m.s. voltage = 1.41 Solution: $R_B = 5.6$ kΩ $I_E = 1.25$ mA $R_B = 36$ kΩ.
V, mean frequency = 10 MHz, maximum instantaneous frequency = 10.018 MHz (deviation 18 kHz).

Q4

More candidates could calculate the Thevenin equivalent than were able to explain how to measure the parameters.

There were several equally valid methods used to calculate the parameters although few used Thevenin to replace the 10 V source and first potential divider. Some unnecessarily attempted to prove the maximum power transfer theorem.

Solution: 4 V and 2 Ω. Maximum power is 2 W when R_L is 2 Ω.

Q5
In view of the importance of operational amplifiers in analogue electronics it is encouraging that the majority of candidates were able to perform correctly the calculation of the resistor required to realise a specified output voltage expression assuming ideal op-amps.

The most important of the parameters used to specify a practical operational amplifier are the slew-rate, the gain-bandwidth product and, to a lesser extent, the offset voltage. However few candidates had any knowledge of the important limitation of the operational amplifier, its slew-rate - and very few were able to calculate the upper frequency limit to linear operation that this imposes on the simple non-inverting stage with a gain of 100.

The non-ideal properties of operational amplifiers and their consequences should be given more attention than appears to be the case at present.

Solution: 15.9 kHz, 1 kΩ.

Q6
The universally poor performance on this question is both disappointing and surprising. The first part requires a simple phasor diagram involving just three phasors (the voltages across the capacitor, the resistor and the transformer) in a triangle. The output voltage phasor is from the centre point of the transformer phasor to the junction of the resistor and capacitor phasors. It is easy to see that the locus of the output phasor is, in fact, a semicircle.

The second part requires some simple ac analysis to find the magnitude and phase of the output voltage as the frequency is varied together with sketches of these functions. So few candidates attempted this part suggests that the study of ac circuit analysis is being neglected.

The main use is as a phase shifter since the amplitude of the output voltage remains constant as the frequency is varied and the phase shift can be calculated from $-2\arctan(\omega CR)$.

Q7
Discrete active components, FETs and BJTs for example, are still important in modern analogue circuitry and it is encouraging to see that candidates are able to tackle a question that represents a practical requirement even if the results are generally disappointing.

Nearly all candidates could define and determine the mutual conductance but relatively few adopted the correct strategy for designing the resistors needed to meet the given specification.

Most candidates started by considering the input base part of the circuit. Practical amplifier design usually starts by considering the output requirements and this is the approach that should be used in this question.

Many candidates were confused by using the old-fashioned *h*-parameters. The BJT is fundamentally a voltage-controlled device so the key parameter is g_m not β or h_{fe} and if an equivalent circuit is used it should be based on a voltage-controlled current source.

The gain is $g_m R_L$. From this the ratio of the gains gives R_C. $g_m R_C$ = 270 gives g_m and thus I_E.

The required base bias resistor can be found using simple potential divider theory. Because the current gain is large the effect of the quiescent base current can be neglected.

Solution: R_B = 5.6 kΩ I_E = 1.25 mA R_B = 36 kΩ.
Check: $I_B \times R_B || 22$ kΩ < 85 mV

Q8
The solution of three phase questions is generally facilitated by the drawing of a circuit diagram showing the connection of the generator to the load. Although not called for, most candidates did draw such a circuit and this helped many of them. However there was still considerable confusion about the value of the line voltage to be used and although the load impedance was usually calculated correctly this adversely affected the load current values in far too many solutions. The real and reactive powers were similarly affected. Most candidates quoted formulae for the powers. It is better to consider the equivalent circuit for the load and see that the real power must be the $|I|^2R$ loss in the resistors and the reactive power must be the $|I|^2\omega L$ loss in the inductors so that cosine and $\sin\phi$ do not need to be calculated.

Far too many candidates wasted time calculating individual voltage and current components. The question clearly only asks for the magnitudes of voltages and currents.

The principles of power factor correction were generally well known but relatively few candidates were able to quantify these correctly and as a result few were able to show that the delta connection had the advantage of a lower capacitance value but at a higher working voltage.

Solution: line voltage = 416 V line current = 19.3 A load current = 11.2 A.
Real power = 7.4 kW reactive power = 11.7 kW.
Delta capacitor = 71.5 μF star capacitor = 215 μF

SUBJECT C108 – SOFTWARE AND INFORMATION SYSTEMS ENGINEERING

Comments on Individual Questions:

Q1
Most students demonstrated a high degree of knowledge concerning this question.

Q2
Most students were capable of understanding the software testing stages although some used their skills of deduction when interpreting the meaning of each stage. Fewer students understood the phasing of these stages which indicates that they have not read as thoroughly as they might have done.

Q3
There was clear evidence that many students do not understand the fundamentals of translating data structure diagrams into database constructs. This lack of elementary database design knowledge was unexpected considering the popularity of databases in industrial and commercial settings.

Q4
Low level operating constructs were something that most students have never considered. Once again, a lack of appropriate reading may be responsible for a very weak set of marks.

Q5
This question tested the candidates knowledge concerning a developers considerations and the modern tools that they could use. The students' scripts showed a clear demarcation between those that are aware of software development issues, and those that have not addressed this problem yet.

Q6
Most students answered the project management part of this question with confidence and skill. However, when their conceptions concerning software engineering and information systems development were tested, some were a little weak.

Q7
Clearly, object oriented programming is very popular. However, most students did not understand abstract data types and some had difficulty understanding the values of modularity. Once again, technical books seem to have been neglected as vehicles for student learning.

Q8
Once again, an operating system type of question revealed a significant shortfall in the kind of technical understanding that can be obtained from the books listed in the reading list.

Overall, although the question paper was set to test each student's vocational and theoretical (reading list) knowledge. It was clear that the weaker students had not studied the literature very much. However, this year was quite pleasing because the technical orientation of some students was better than before and this was reflected in the marks awarded. The few students that combined software engineering knowledge with some form of theoretical underpinning were rewarded with the higher marks.