IVQs in Electrical and Electronic Engineering (8030-2000)

City&Guilds

Level 5 IVQ Advanced Technician Diploma in Electrical and Electronic Engineering
– Electrical Engineering
– Electronic Engineering
(8030-23) (500/5805/8)

www.cityandguilds.com
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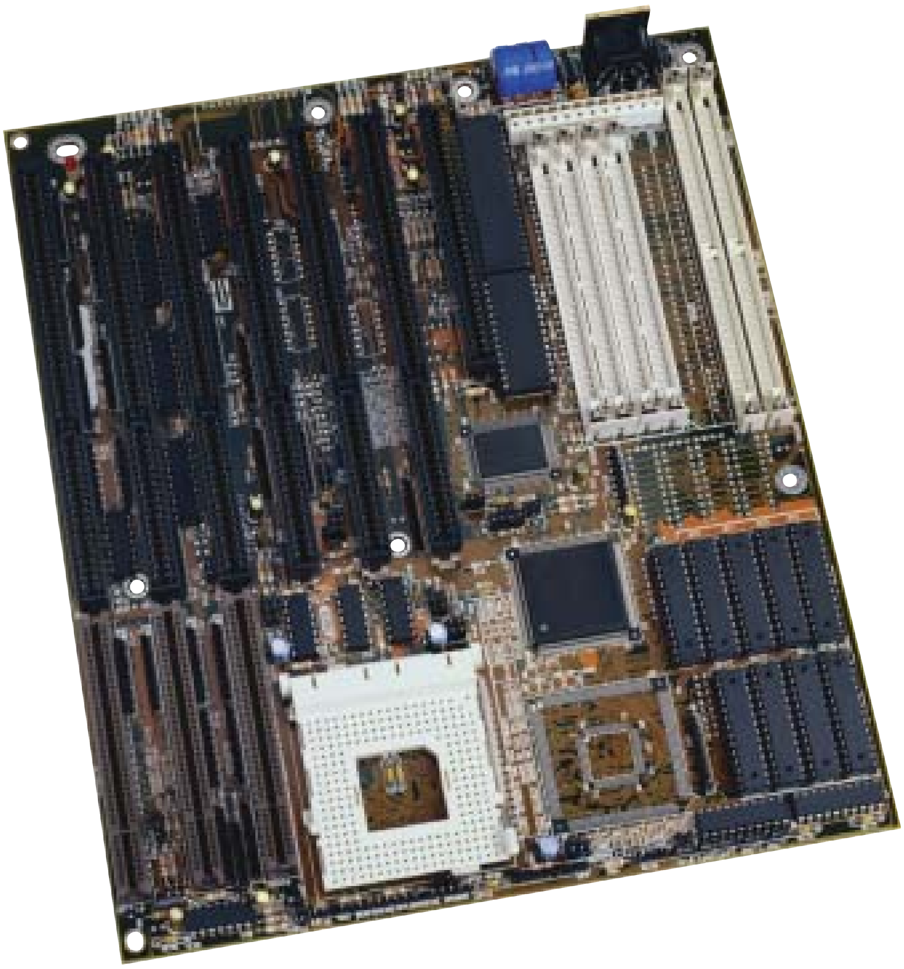
Qualification handbook for centres



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Important notice

Following the accreditation of the Technician IVQs in Electrical and Electronic Engineering (8030-2000) on the National Qualifications Framework of England, Wales and Northern Ireland (NQF), some changes have been made to the qualification, at the request of the Office of the Qualifications and Examinations Regulator (Ofqual), the qualifications regulator in England.

These changes took effect on 1 June 2009 and are outlined on this page.

Note: the content of the qualifications has not changed following accreditation.

Changes to the qualification titles
The qualification titles have changed as follows:

Advanced Technician Diploma in Applied Electrical Engineering (8030-23)
changed to
Level 5 IVQ Advanced Technician Diploma in Electrical and Electronic Engineering (Electrical Engineering) (8030-23)
Accreditation number: 500/5805/8

Advanced Technician Diploma in Applied Electronic Engineering (8030-23)
changed to
Level 5 IVQ Advanced Technician Diploma in Electrical and Electronic Engineering (Electronic Engineering) (8030-23)
Accreditation number: 500/5805/8

Changes to the unit titles
Following the accreditation of the Technician IVQs in Electrical and Electronic Engineering, each unit has been given an accreditation reference number which will appear on the Certificate of Unit Credit.

The content of the units is unchanged.

Level 5 IVQ Advanced Technician Diploma in Electrical and Electronic Engineering (Electrical Engineering) (8030-23)
Accreditation number: 500/5805/8

Mandatory units
M/502/2613 – Engineering Project Practical Assignment
T/502/2614 – Advanced Electrical Principles

Optional units (one required)
F/502/2616 – Distribution and Utilisation of Electrical Energy
J/502/2617 – Generation and Supply of Electrical Energy
L/502/2618 – Electrical Plant and Equipment

Level 5 IVQ Advanced Technician Diploma in Electrical and Electronic Engineering (Electronic Engineering) (8030-23)
Accreditation number: 500/5805/8

Mandatory units
M/502/2613 – Engineering Project Practical Assignment
T/502/2614 – Advanced Electrical Principles

Optional units (one required)
A/502/2615 – Control Systems and Applications
R/502/2619 – Micro-electronic Circuits and Systems

Registration for theory examination
Registration process for the theory examination has not changed.

Result submission for practical assessment
Result submission process for the practical assessments has not changed.

Change to the grading
The grade 'Credit' has been changed to 'Merit'. All other grades are unchanged. The content of the units concerned is also unchanged.

Notification of Candidate Results (NCR) and Certificate of Unit Credit (CUC)
Notification of Candidate Results (NCR) and Certificate of Unit Credit (CUCs) continue to be available on completion of each assessment (theory or practical).

Final certificate will be issued on successful completion of all the required assessments.

'Theory only' routes
The 'Theory only' routes continue to be available as unaccredited qualifications.

Changes to the certificate layout
Certificates issued on completion of an accredited IVQ show the accredited title and the accreditation number for the qualification. The level in the accredited title refers to the NQF level the qualification is accredited at.

The certificate also lists all the units achieved, including the grade and the unit accreditation number.

The certificate carries the logos of the regulatory authorities in England, Wales and Northern Ireland indicating that the NQF accreditation only applies to these countries.

Levels of City & Guilds qualifications

All City & Guilds qualifications are part of an integrated progressive structure of awards arranged over eight levels, allowing people to progress from foundation to the highest level of professional competence. Senior awards, at levels 4 to 7, recognise outstanding achievement in industry, commerce and the public services. They offer a progressive vocational, rather than academic, route to professional qualifications. An indication of the different levels and their significance is given below.

NQF level#	City & Guilds qualifications/programmes	Other qualifications*
8	Fellowship (FCGI)	Doctorate
7	Membership (MCGI) Master Professional Diploma Level 5 vocational awards NVQ/SVQ Level 5	Master's Degree Postgraduate Diploma Postgraduate Certificate
6	Graduateship (GCGI) Associateship (ACGI)**	Bachelor's Degree Graduate Certificate and Diploma
5	Level 5 IVQ Advanced Technician Diploma Full Technological Diploma	Higher National Diplomas Foundation Degree Diplomas of Higher and Further Education
4	Licentiateship (LCGI) Higher Professional Diploma Level 4 vocational awards NVQ/SVQ Level 4	Certificate of Higher Education
3	Level 3 IVQ Advanced Diploma Level 3 IVQ Specialist Advanced Diploma*** Level 3 IVQ Technician Diploma Level 3 vocational awards NVQ/SVQ Level 3	A Level Scottish Higher Advanced National Certificate in Education BTEC National Certificate/Diploma
2	Level 2 IVQ Diploma Level 2 IVQ Specialist Diploma*** Level 2 IVQ Technician Certificate Level 2 vocational awards NVQ/SVQ Level 2	GCSE grades A*-C Scottish Intermediate 2/Credit S Grade BTEC First Certificate
1	Level 1 IVQ Certificate Level 1 vocational awards NVQ/SVQ Level 1	GCSE grades D-G Scottish Intermediate 1/General S Grade Scottish Access 1 and 2

National Qualifications Framework of England, Wales and Northern Ireland (NQF)
* Broad comparability in level
** Only graduates of the City & Guilds College, Imperial College of Science, Technology and Medicine, are awarded the Associateship (ACGI)
*** Part of a new qualification structure which is being introduced across the IVQ provision
IVQ International Vocational Qualifications
NVQ National Vocational Qualifications

IVQ in Electrical and Electronic Engineering 8030 (2000)

About City & Guilds

We provide assessment and certification services for schools and colleges, business and industry, trade associations and government agencies in more than 100 countries. We have over 120 years of experience in identifying training needs, developing assessment materials, carrying out assessments and training assessment staff. We award certificates to people who have shown they have mastered skills that are based on world-class standards set by industry. City & Guilds International provides a particular service to customers around the world who need high-quality assessments and certification.

Introduction to this programme

We have designed the Advanced Technician Diplomas in Electrical and Electronic Engineering programme for those undergoing training or employed in this area of work. The programme aims to reflect the international nature of the knowledge and skills and activities needed for different countries or cultures.

We provide certificates for all work-related areas at seven levels within our structure of awards shown in appendix B. This programme covers level 4. The standards and assessments for the diploma (level 3) and the certificate (level 2) are published separately.

Certificate
The certificate (about 350 guided learning hours) provides a broad introduction to the theory and practical sides of engineering for a front-line worker or a person beginning an academic training programme.

Diploma
The diploma (about 600 guided learning hours) provides more practice involving a broader range of skills appropriate to a person who may also supervise, or who is going on into higher education.

Advanced diploma
The advanced diploma (about 600 guided learning hours) takes these skills to the level appropriate for a person preparing for or working in first-level management. It is also appropriate for someone who wants to receive specialised training at a high level.

We stress that these figures are only a guideline and that we award certificates and diplomas for gaining and showing skills by whatever mode of study, and not for periods of time spent in study.

Full Technological Diploma
We will award the Full Technological Diploma (FTD) in Engineering to someone who is at least 21, who has had at least two years relevant industrial experience, and who has successfully finished the assessments for the diploma and advanced diploma levels of this award. If candidates enter for this diploma, they must also send us a portfolio of evidence to support their application.

Making entries for assessments

Candidates can only be entered for the assessments in this subject if the approved examination centre agrees. Candidates must enter through an examination centre we have approved to carry out the assessments for 8030 Technician Awards in Engineering.

There are two ways of entering candidates for assessments.

Internal candidates
Candidates can enter for examinations if they are taking or have already finished a course at a school, college or similar training institution that has directed their preparation whether by going to a training centre, working with another institution, or by open learning methods.

External candidates
These are candidates who have not finished a programme as described above. The examination centres must receive their application for entry well before the date of the examination concerned. This allows them to act on any advice you give about assessment arrangements or any further preparation needed. External candidates carrying out practical assignments and projects will need extra time and guidance to make sure that they meet all the requirements for this part of the assessment.

In this publication we use the term 'centre' to mean a school, college, place of work or other institution.

Resources

If you want to use this programme as the basis for a course, you must read this booklet and make sure that you have the staff and equipment to carry out all parts of the programme. If there are no facilities for realistic practical work, we strongly recommend that you develop links with local industry to provide opportunities for hands-on experience.

Summary of assessment

There is one level of this award

Advanced Diplomas

We use a numbering system to allow entries to be made for our awards. The numbers used for this programme are as follows.

Award number

8030-23	Advanced Technician Diploma in Applied Electrical Engineering Advanced Technician Diploma in Applied Electronic Engineering

We use award numbers to describe the number and level of the award.

Component numbers
220 Engineering Project Practical Assignment
221 Advanced Electrical Principles
222 Control Systems and Applications
223 Distribution and Utilisation of Electrical Energy
224 Generation and Supply of Electrical Energy
225 Micro-electronic Circuits and Systems
226 Electrical Plant and Equipment
227 Advanced Mathematics

This unit is an option recommended for candidates entering Higher Education.

We use component numbers to show units for which we may award a Certificate of Unit Credit.

We use these numbers throughout the booklet. You must use these numbers correctly if you send forms to us.

Advanced Technician Diploma in Applied Electrical Engineering
To carry out what is needed for the Advanced Technician Diploma in Applied Electrical Engineering, candidates must be successful in all of the following assessments.

[8030-23-220] Engineering Project

8030-23-221 Advanced Electrical Principles

Candidates must also be successful in one of the following units

8030-23-223 Distribution and Utilisation of Electrical Energy

8030-23-224 Generation and Supply of Electrical Energy

8030-23-226 Electrical Plant and Equipment
(Total two written papers)

The practical assessments are carried out during the learning programme and should be finished by the date of the written examination so you can send all the results to us. (See appendix A.)

To receive this award candidates must complete the following practical assignment.

220/1
(Total one practical assignment)

Advanced Technician Diploma in Applied Electronic Engineering
To carry out what is needed for the Advanced Technician Diploma in Applied Electronic Engineering, candidates must be successful in all of the following assessments.

[8030-23-220] Engineering Project

8030-23-221 Advanced Electrical Principles

Candidates must also be successful in any one of the following units:

8030-23-222 Control Systems and Applications

8030-23-225 Micro-Electronic Circuits and Systems
(Total two written papers)

The practical assessments are carried out during the learning programme and should be finished by the date of the written examination so you can send all the results to us. (See appendix A.)

To receive this award candidates must complete the following practical assignment.

220/1
(Total one practical assignment)

Advanced Technician Diploma in Electrical Engineering Theory
To carry out what is needed for the Advanced Technician Diploma in Electrical Engineering Theory, candidates must be successful in all of the following assessments.

[8030-23-220] Engineering Project

8030-23-221 Advanced Electrical Principles

Candidates must also be successful in one of the following units:

8030-23-223 Distribution and Utilisation of Electrical Energy

8030-23-224 Generation and Supply of Electrical Energy

8030-23-226 Electrical Plant and Equipment
(Total two written papers)

Advanced Technician Diploma in Electronic Engineering Theory

To carry out what is needed for the Advanced Technician Diploma in Electronic Engineering Theory, candidates must be successful in all of the following assessments.

8030-23-221	Advanced Electrical Principles

Candidates must also be successful in any one of the following units:

8030-23-222	Control Systems and Applications
8030-23-225	Micro-Electronic Circuits and Systems

(Total two written papers)

Fixed and free date assessments

We provide assessments in two ways.

a Fixed date
These are assessments which are carried out on dates and times we set. These assessments have no brackets around their numbers.

b Free date
These are assessments which are carried out at a college or other training establishment on a date or over a period which the college chooses. These assessments have brackets around their numbers.

In this programme the written assessments are fixed date. The practical assignments and the project are free date.

You must carry out assessments according to our International Directory of Examinations and Assessments. If there are any differences between information in this publication and the current directory, the directory has the most up-to-date information.

Results and certification

Everyone who enters for our certificates, diplomas, and advanced diplomas receives a 'Notification of Candidate Results' giving details of how they performed.

If candidates successfully finish any assessment within this programme (for example, any one of the examination papers) they will receive a Certificate of Unit Credit towards the certificate or diploma for which they are aiming. We grade coursework assessments (practical assignments) as pass or fail. We grade written assessments on the basis of fail, pass, credit or distinction. The Certificate of Unit Credit will not mention assessments which they do not enter, which they failed or from which they were absent.

Each certificate or diploma clearly states what candidates need for full certification at the relevant level, allowing schools, colleges and employers to see whether they have met the full requirements.

If candidates successfully finish all the requirements for a full certificate or a diploma, they will automatically receive the appropriate certificate.

We will send the 'Notification of Candidate Results', Certificates of Unit Credit, Certificates, diplomas and advanced diplomas to the examination centre to be awarded to successful candidates. It is your responsibility to give the candidates the certificates. If candidates have a question about the results and certificates, they must contact you. You may then contact us if necessary.

We will also send the examination centre a results list showing how all candidates performed.

How to offer this programme

To offer this programme you must get approval from us. There are two categories of approval.

Subject approval
We give approval to offer a teaching course based on this syllabus.

Examination centre approval
We give approval to enter candidates for examinations.

To be approved by us to offer a teaching course you must send us the application form.

To enter candidates for examinations you must be approved by us as an examination centre. For this programme it is possible to act as a registered examination centre only, and accept external candidates. Approved examination centres must provide suitable facilities for taking examinations, secure places to keep the examination papers and materials, and may have an appointed visiting verifier to review practical work.

After we have received and accepted an application, we will send an approval letter confirming this. You can then send entries in at any time using the International Directory of Examinations and Assessments for guidance.

Please note that in this section we have provided an overview of centre approval procedures. Please refer to the current issue of 'Delivering International Qualifications – Centre Guide' for full details of each aspect of these procedures

Other information

Designing courses of study

Candidates for the various Technician Awards in Engineering will have come from different backgrounds and will have different employment and training experiences. We recommend the following:

- carry out an assessment of the candidates' achievements so you can see what learning they already have and decide the level of entry they will need; and
- consider what learning methods and places will best suit them.

When you assess a candidate's needs, you should design teaching programmes that consider:

- what, if any, previous education qualifications or training the candidate has, especially in the various general vocational education certificates we provide; and
- what, if any, previous practical experience the candidate has which is relevant to the aims of the programme and from which they may have learned the relevant skills and knowledge.

When you choose learning methods and places, you should consider the results of your assessments and whether the following are available.

- Open or distance learning material.
- Workplace learning that can be carried out on site or between you and a local workplace. This will allow the candidates access to specialised equipment and work experience.
- Working with other registered centres to share facilities.
- Opportunities for co-operative learning between candidates for different certificates who need to gain similar skills.

As long as the candidates meet the aims of this learning programme the structures of courses of study are up to you. So, it is possible to include extra topics that meet local needs.

You should avoid teaching theory alone. As far as possible the practical work should be closely related to work in the classroom so that candidates use their theory in a realistic work environment. You can use formal lectures in the classroom with appropriate exercises and demonstrations. Candidates should keep records of the practical work they do so they can refer to it at a later date.

We assume that you will include core skills, such as numeracy, communication, working with people, and organisation and planning throughout a teaching programme.

Presentation format of units

Competence statements

Each unit consists of a number of competence statements which are generally followed by a range statement.

For example:

'225.1 Define various types of signals encountered in electronic systems,
Signals: analogue, digital/pulse, video'

In the above statement the word 'signals' is given as a range which the candidate should be familiar with. Candidates should cover the complete range. When a range starts with the abbreviation 'eg' the candidate only needs to cover some of the ranged areas or you can use suitable alternatives.

Competence statements cover practical skills and knowledge requirements. The knowledge needed is closely linked to the practical competences, so it is best to teach the two together so the candidate understands the topic more.

Practical assignments

You should make sure all practical assignments are supervised and instructors should make sure that the results reflect the candidate's own work. You must hold all the documents and associated materials in a file (portfolio) for each candidate for eight weeks after the application for a certificate. You must also keep separate records of the dates of all attempts by each candidate.

Entry levels

We consider that the following programmes are relevant preparation for this programme.

Technician Diplomas in Electrical and Electronic Engineering (8030)

We also consider that the following Pitman Qualifications award is relevant alongside this programme.

English for Speakers of Other Languages – higher intermediate level

Progression routes and recognition

A number of universities and other higher-education institutions in the UK will accept success at diploma or advanced diploma level of this programme for direct entry onto higher-level programmes. The decision to accept a candidate on to a degree programme, and the level of entry, is up to the institution. We provide details of organisations who recognise achievement in this programme.

Useful publications

We can provide a list of suggested text books covering specific areas of this programme. We may also know about other support materials. You should make sure that you have the latest information. We will automatically send updated lists to centres we have approved to offer this programme.

4516 Crystal Mark

Clarity approved by Plain English Campaign

Plain English Campaign's Crystal Mark only covers the regulations

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Syllabus
IVQ in Electrical and Electronic Engineering 8030

Component numbers and titles

220	Engineering Project practical assignment
221	Advanced Electrical Principles
222	Control Systems and Applications
223	Distribution and Utilisation of Electrical Energy
224	Generation and Supply of Electrical Energy
225	Micro-electronic Circuits and Systems
226	Electrical Plant and Equipment
227	Advanced Mathematics (optional unit)

220 Engineering project practical assignment

Introduction

The intention of this unit is to provide an opportunity for candidates to solve a realistic engineering problem which requires the application and integration of other modules within the Advanced Diploma programme of study.

The aim of the unit is for candidates to acquire:

- planning, organisation and communication skills
- experience in methods and techniques for product and process improvement
- and to develop personal qualities such as creative ability, imagination, initiative and maturity

Practical competences

The candidate must be able to do the following:

Specification and analysis

220.1 Select the problem to be solved.

220.2 Identify the main elements of the problem.

220.3 Define the objectives of the problem.

220.4 Prepare a specification of the problem to be solved.

220.5 Determine the tasks to be performed to enable the attainment of the objectives.

220.6 Organise the tasks chronologically.

Scheduling and planning

220.7 Plan the initial programme for solving the problem.

220.8 Estimate the resource requirements for each of the tasks.

220.9 Estimate the time needed to complete each task.

220.10 Prepare a schedule of work.

Execution and performance

220.11 Obtain the information necessary to solve the problem.

220.12 Select equipment or methods of operation to carry out each task.

220.13 Perform experimental/investigatory work necessary for the execution of the tasks.

Evaluation and communication

220.14 Evaluate the validity of the results.

220.15 Assess the success of the work undertaken.

220.16 Make recommendations for further work.

220.17 Prepare a project report to specified layout.
Layout: eg title page, summary, contents page, list of figures, tables, symbols as required, introduction, work carried out, evaluation of the results, conclusions as related to the aims of the project, practical recommendations, references and appendices

220.18 Ensure that the body of the report includes the following work.
Work: eg relevant background information, clear and precise documentation of the aims of the project, relevant theory, previous work undertaken by other people within the area of activity, the actual work undertaken

220.19 Prepare material for an oral presentation.
Materials: eg slides/transparencies, flip charts, audio or video tapes, supporting notes

220 Engineering project – Practical assignment

Practical assignment 220/1: Solve an engineering problem

1 Competence references

220.1-220.19

2 Preparation

2.1 **Location of test**
The training centre or other venue where supervision and appropriate working conditions will be provided.

2.2 **Requirements**
Paper, pens, pencils and ruler or a computer system running appropriate software (eg word processing, computer aided draughting software) and a printer connected to the system, with paper loaded and set up ready to print.

Manuals for software.

Copy of section 3 and section 6.

2.3 **Instructor notes**
Candidates are required to select and solve individually an engineering problem which can be realistically achieved (see section 6 for suitable suggestions) within 60 hours. The project must be agreed between candidate and instructor and must take into account the amount and level of work required and the resources available. The nature of the work must demonstrate the candidate's ability at advanced diploma level.

The project is generally considered to be a student centred activity. The instructor's main responsibility is to create an effective learning environment. In particular the instructor should check the project objectives, monitor the candidate's progress, advise on project progression, exercise leadership if needed, assist in development of the candidate's skills and knowledge and counsel as appropriate.

Candidates may carry out research and produce materials during the allocated time but the report must be produced at the centre under supervision.

It is recommended that candidates should be allowed adequate time to produce the final report. Candidates may use word processors to produce their report provided they have sufficient word processing skills to do so efficiently.

On completion of the report, candidates are required to carry out an oral presentation of their work to the instructor and peer group. It is envisaged that such a presentation will take between 15-30 minutes.

3 Candidates' instructions

3.1 You are requested to select and solve a realistic engineering problem. At each stage of this project you must refer to your instructor for continuous guidance and direction. You must keep a log book summarising the work undertaken each week. This log book will be useful in producing the final report. You have 60 hours to complete this assignment.

3.2 Select an appropriate project and agree it with your instructor.

3.3 Maintain on a regular basis a log book or diary detailing work undertaken.

3.4 Identify the main elements of the problem to define the objectives of the project.

3.5 Prepare a detailed specification of the problem and organise the tasks to be undertaken chronologically (network diagram or similar).

3.6 Plan the initial programme for solving the problem and determine the resource requirements in terms of time, equipment and materials.

3.7 Prepare a schedule of the work to be carried out (Gantt chart or similar).

3.8 Undertake research in order to obtain the information necessary to solve the problem.

3.9 Select equipment or methods of operation to progress the project.

3.10 Carry out the work necessary for the completion of the project.

3.11 Evaluate the success of the work undertaken and make recommendations for further work.

3.12 Prepare a project report using an appropriate format and layout (see section 6.2), which should contain all the work produced in 3.2-3.11 above.

3.13 Prepare an oral presentation and present it to your instructor/colleagues.
Oral presentation: eg notes, overhead transparencies

3.14 Ensure your name is on the report and hand it in to your instructor.

4 Marking

4.1 Project completed in approximately 60 hours. ( )

4.2 Realistic engineering project selected and agreed with instructor. [ ]

4.3 Log book or diary maintained throughout the project. [ ]

4.4 The main elements of the problem identified and the objectives defined. [ ]

4.5 4.5.1 Detailed specification prepared [ ]

4.5.2 Tasks to be undertaken organised chronologically [ ]

4.5.3 Network diagram or similar produced. [ ]

4.6 4.6.1 Initial programme planned [ ]

4.6.2 Resource requirements determined in terms of time, equipment and materials. [ ]

4.7 Schedule of work prepared (Gantt chart or similar). [ ]

4.8 Appropriate research undertaken and relevant information obtained. [ ]

4.9 Appropriate equipment and methods to progress the work selected [ ]

4.10 Necessary work carried out to complete project. [ ]

4.11

4.11.1 Success of the project evaluated and work assessed. [ ]

4.11.2 Recommendations for further work made. ( )

4.12 Project report completed. [ ]

4.13 Oral presentation prepared and presented. [ ]

4.14 Report handed in. [ ]

5 Assignment completion

The candidate will have satisfactorily completed this assignment if successful in all the items marked with a [ ].

Candidates who fail to achieve the requisite number of outcomes should be encouraged to carry out further work in order to complete the assignment satisfactorily.

6 Assignment documentation

6.1 **Choosing a project**

The theme of the project is to investigate a particular section of a company and to improve the section in terms of costs or procedures (manufacturing, maintenance, marketing, management). Possible areas for project work are listed below:

- improvement of the efficiency or effectiveness of an existing process
- introduction and commissioning of new plant
- modification of existing equipment to perform new or additional operations
- improvement of maintenance procedures on selected plant or equipment
- introduction of new procedures for measuring, testing and calibrating products or equipment
- standardisation of component parts for product assembly.

6.2 **Project report writing**

The general layout of the project report should be as follows:

title page
summary
contents page
list of figures, list of tables, list of symbols, as required
introduction
work carried out
evaluation of the results
conclusions as related to the aims of the project
practical recommendations
references and appendices.

The work carried out should include:

relevant background information
clear and precise documentation of the aims of the project
relevant theory previous work undertaken by other people
within the area of activity the actual work undertaken

221 Advanced electrical principles

Introduction

This unit builds on the electrical principles previously studied in the diploma level. It aims to cover a variety of fundamental aspects of circuit and network theory. In addition, a section on reliability is included. Much of the work in this unit requires a compatible level of supporting mathematics to assist the candidates to put into practice the various theoretical concepts. It is not intended that the mathematics is separately examined.

Knowledge requirements

Instructors must ensure that candidates are able to:

Circuits and networks

221.1 Calculate steady state current and voltage conditions in ac circuits using symbolic notation (j-operator).
Ac circuits: resistors, capacitors and inductors in series and parallel circuits

221.2 Calculate the currents and voltages in ac circuits using mesh and nodal analysis.
Networks: two loops containing R, L and R, C

221.3 Calculate currents, voltages and power in single-phase and balanced three-phase circuits
Circuits: resistance and reactance connected in series and in parallel

221.4 Calculate rms voltages and currents of waveforms containing harmonics.

221.5 Determine the effects of harmonics on power factor and power.

221.6 Calculate voltage, current, power and power factor in circuits connected across an ac supply containing harmonics.
Circuits: series and parallel containing resistance and either inductance or capacitance
Harmonics: fundamental, 2nd, 3rd

221.7 Explain harmonic resonance and show in circuits containing R, L and C, at the nth harmonic, $n\omega L = 1/n\omega c$

221.8 Define the performance of a four terminal, two port network in terms of Y parameters (Y_{11}, Y_{12}, Y_{21} and Y_{22}) and Z parameters (Z_{11}, Z_{12}, Z_{21} and Z_{22}).

221.9 Derive general expressions for the performance of two port, four terminal, active and passive networks in terms of their Y and Z parameters.
Performance: input impedance, output impedance, forward voltage and forward current ratios

221.10 Determine the performance, given values of external components and the appropriate Y or Z parameters, of simple four terminal networks.
Performance: input impedance, forward voltage, forward current ratios

221.11 Define the surge/characteristic impedance of a line/network.

221.12 Explain terms associated with the representation of transmission of lines.
Terms: infinite, finite, loss free

221.13 Explain types of wave associated with transmission lines.
Wave: incident, reflected, standing

221.14 Explain how reflected and standing waves are generated under mismatched conditions.

221.15 Define attenuation in dBs and explain the operation of resistive attenuators.

221.16 Solve problems associated with attenuators.
Problems: calculation of surge impedance, attenuation, component values
Attenuators: single section symmetrical T and π

221.17 Solve problems involving series and parallel tuned-circuits.
Problems: calculation of dynamic resistance, inductance, capacitance, Q factor, resonant (centre), frequency, bandwidth

221.18 Solve problems where a tuned-circuit is mutually coupled to a resistive load.
Problems: calculation of dynamic resistance, inductance, capacitance, Q factor, resonant (centre), frequency, bandwidth

221.19 Derive an expression for the input impedance of a tuned-circuit coupled by mutual inductance to a secondary tuned-circuit.

221.20 Sketch graphs to illustrate the changes in the response curve of secondary current/frequency as the value of the coupling coefficient k_c is increased.

221.21 Define critical coupling and state that the value of coupling coefficient for critical coupling is $k_c = 1/\sqrt{Q_p Q_s}$

221.22 State that the 3dB bandwidth of critically-coupled identical tuned-circuits is $B = \sqrt{2}\,\frac{fr}{Q}$

221.23 Perform calculations on tuned critically coupled-circuits.
Calculations: undamped and damped Q factor, mutual inductance, self inductance, capacitance, coupling coefficient

221.24 Analyse dc and ac circuits using circuit theorems.
Theorems: Thevenin, Norton
Circuits: restricted to two loops only

221.25 Use Star-Delta and Delta-Star transformations to simplify circuits consisting of resistance and reactance.
Circuits: T (Star), π (Delta)

221.26 Perform calculations involving the conversion of Thevenin to Norton and Norton to Thevenin equivalent circuits.

Filters

221.27 Sketch the ideal frequency response characteristics of a range of filters.
Filters: low pass, high pass, band pass, band stop

221.28 Sketch circuits of single-pole RC filters.
Filters: low pass, high pass

221.29 Sketch frequency response characteristics of filter network and indicate the 3dB frequency.
Filters: low pass, high pass

221.30 Determine the ultimate rate of signal voltage attenuation for a single-pole RC filter circuit (6dB/octave 20dB/decade)

221.31 Sketch waveforms to show the effect of passing a complex waveform through low-pass and high-pass filter circuits.

221.32 Perform calculations to establish an expression for the resulting waveform when passing a complex waveform through filter networks.
Complex waveforms: limited to a fundamental plus 1 harmonic
Filter Networks: low pass, high pass

221.33 Sketch LCR band-pass and band-stop filter circuits and their frequency response curves.

221.34 Describe the use of operational amplifiers to replace inductors in active filters, and state the benefits.

221.35 Sketch circuits of operational amplifier active filters.
Filters: high pass, low pass

221.36 Derive transfer functions in terms of jw for operational amplifier active filters.
Filters: high pass, low pass

221.37 Perform calculations on active filters.
Calculations: mid band gain, high and low -3dB frequency, component values

Transients and transformers

221.38 Explain that electrical transients are generated by circuits containing components that store and dissipate energy.
Components: capacitors, inductors (energy storage), resistors, circuit losses (energy dissipation)

221.39 Explain that CR and LR series circuits experience current and voltage exponential growth or decay when subjected to a step input.

221.40 Sketch graphs of variation of current and voltage in CR and LR series circuits subjected to a step change and calculate time constant.

221.41 Calculate instantaneous voltage and current values in CR and LR series circuits.

221.42 Show using the formulae $\frac{N_p{}^2}{N_s} = \frac{R_p}{R_s}$ that the transformer can be used for impedance matching where Z_p = primary load, Z_s = secondary load, N_p = primary turns, N_s = secondary turns.

221.43 Perform calculations on transformer matching using the formulae in 221.42.

221.44 Define transformer regulation as the change in secondary voltage between no-load and full-load, usually expressed as a percentage of secondary emf.

221.45 Describe with the aid of diagrams the construction and application of a range of transformers.
Transformers: auto, current, power, audio frequency, radio frequency

Reliability

221.46 Explain the importance of high reliability in typical electrical and electronic applications.

221.47 Define reliability (R) in terms of probability of success for a specified time.

221.48 Define mean time between failures (m).

221.49 Define failure rate (λ) and explain the unit percent per 1000 hours.

221.50 Draw and explain a graph of failure rate/time for a system (the bath tub diagram).

221.51 State the relationship between reliability, failure rate and time. $R = \exp(-\lambda t)$.

221.52 Draw the graph of reliability/time (the survival characteristic).

221.53 Use the law of compound probability to show that the failure rate of a system is the sum of the failure rates of all its component parts.

221.54 Calculate the reliability of a system from the component failure rates, using given data.

221.55 Calculate the reliability of two identical units employed in a main/standby situation.

221.56 Describe the effect on failure rate of operating components well below their power rating.

221.57 Describe how reliability may be improved by controlling the environment in which the system operates.

221.58 Describe why the reliability of hardware, firmware and software is important to ensure the overall reliability of a computer controlled system.

221.59 Explain the importance of accurate reporting and recording of failures.

Associated mathematics

The following section is intended to illustrate the topic areas and the applications of mathematics that the candidates require in order to complete the applications work arising from this unit.

Trigonometric functions

221.60 Represent sine, cosine and harmonic waveforms using $y = A\sin(\omega t + \phi)$ and $y = A\cos(\omega t + \phi)$.

221.61 Use mathematical notation to represent travelling waves on open circuit and short circuit transmission lines.

221.62 Solve equations involving inverse trigonometric functions.
Equations: eg the results of angles being greater than 90, 180, 270, 360 degrees, instantaneous values of waveforms in 221.60, power factor correction

Calculus

221.63 Differentiate, applying standard rules, a range of functions.
Functions: a constant, x^n, $A\cos(x)$, $B\sin(x)$, e^x

221.64 Solve circuit problems involving rates of change.
Rates of change: eg $i = dq/dt$, $v = Ldi/dt$, $V=Cdv/dvt$

221.65 Integrate applying standard rules a range of functions.
Functions: eg 1, x^n, $A\cos(x)$, $B\sin(x)$ etc, $1/(1-x^2)^{-½}$, e^x

221.66 Calculate the area under a graph representing a given function between two points using definite integrals.

221.67 Determine mean and rms values of sine and cosine functions using integration between the limits $0 \rightarrow \pi/2$

221.68 Solve problems involving calculations of mean and rms values of practical waveforms arising from power switching using diodes, thyristors and triacs in phase control and burst firing circuits where the time periods are less than half a cycle.

Exponential functions and complex numbers

221.69 Reduce exponential functions using natural logs (ln) and inverse logs ($\ln^{-1}$) into linear form to solve electrical problems.
Electrical problems: currents, voltages, time, reliability, meantime between failures

221.70 Represent ac quantities using operator jw.

221.71 Represent a complex equation on an Argand diagram.

221.72 Perform addition, subtraction, multiplication and division of complex numbers.

221.73 Use polar form ($r\angle\theta$) in calculations involving division and multiplication of complex numbers.

221.74 Convert polar form of complex numbers to Cartesian form and Cartesian to polar.

Matrices and determinants

221.75 Use matrices to represent performance of 2 port, 4 terminal networks in terms of A, G, H, Y and Z parameters.

221.76 Solve simultaneous equations using determinants.

221.77 Convert from one parameter set to another, eg from Z to Y, G to H.

221.78 Add, subtract and multiply 2 x 2 matrices.

Graphical representations

221.79 Use log/linear graph paper to present frequency response of electrical/electronic circuits in graphical form and interpret practical results.

221.80 Calculate voltage, current and power ratios in dB and represent the results in graphical form by plotting the results against log frequency.

221.81 Calculate phase shift at various frequencies and plot phase (log frequency) along with the results in 221.80 to form a Bode diagram.

Test specification for written paper Advanced Electrical Principles (8030-23-221)

This is a written examination paper lasting two hours with six questions. Candidates must answer **all** questions.

The examination will cover the knowledge specifications:

Topic	Approximate % examination weighting
Circuits and networks	50
Filters	15
Transients and transformers	15
Reliability	20

Introduction

The aim of the unit is to provide a general background in control theory with details of the construction and performance of the associated practical equipment over a range of applications, using an inter-disciplinary approach. Much of the work in this unit requires a compatible level of supporting mathematics to assist the candidates to put into practice the various theoretical concepts. It is not intended that the mathematics is separately examined.

Knowledge requirements

Instructors must ensure that candidates are able to:

Control principles

222.1 Explain a range of terms relating to control systems.
Terms: open and closed loop control, negative and positive feedback, input signal (reference or set value), output signal (reset value), error signal, signal conditioning, open and closed loop transfer functions, comparators, offset, control variable

222.2 Define a closed loop proportional control system as one where the feedback is proportional to the difference between the input and output signals (error).

222.3 Explain why the closed loop formed by the feedback always acts to reduce the amplitude of the error (negative feedback), for the operation of the system to remain stable.

222.4 Describe, with the aid of block diagrams, examples of simple closed loop control systems with proportional feedback.
Examples: control of position, shaft speed, temperature, voltage, pressure

222.5 Explain that in control systems, sensors are required to sense the level of the input and/or the output to provide signals proportional to the quantities being measured and also, an actuator may be required at the output to convert the output signal to a suitable form to drive the load.
Systems: control of position, shaft speed, temperature, voltage, pressure

222.6 Explain that closed loop systems are error actuated and hence the error is never reduced completely to zero.
Systems: control of position, shaft speed, temperature, voltage, pressure

Sensors (transducers)

222.7 Describe, with the aid of diagrams, the construction, the principles of operation, and characteristics of a range of sensors.
Sensors: diaphragm and bellows types including capacity, inductive and piezoelectric transducers for pressure measurement; load cells and strain gauges, including bridges techniques for measurement of weight; thermistors, thermocouples and resistance thermometers for temperature measurement; linear variable differential transformer and resistance potential divider for linear displacement; digital optical encoders for rotational displacement; tacho generators and pulse counting techniques with magnetic induction for measurement of angular velocity; venturi with pressure transducers, turbine meters and doppler frequency shift meters for measurement of liquid flow

222.8 Select appropriate sensors/transducers for common applications using manufacturers' or suppliers' data sheets to establish practical specifications and describe the requirements for signal conditioning where appropriate.

222.9 Perform calculations relating to the performance of sensors/transducers, using graphical characteristics and established formulae.
Calculations: eg bridge calculations with resistors and strain gauges, voltage calculations with thermocouples and thermistors, (working in absolute temperature) Bernoulli's equations for flow measurement

Amplifiers and actuators

222.10 Explain why some form of power amplification is required in most practical forms of closed loop proportional control system.

222.11 Explain that in some types of control systems it is often more convenient for the actuator to be an integral part of the amplifier.
Types of system: hydraulic, pneumatic

222.12 Describe, with the aid of diagrams, the construction and principle of operation of various types of amplifier.
Types: electronic (differential-input operational and power types), hydraulic, pneumatic

222.13 Explain how an electronic differential amplifier may function as an error detector in a closed loop system.

222.14 Compare the characteristics of the types of amplifier in 222.12, using manufacturers' or suppliers' data.
Characteristics: forward transfer ratios, power output, operating frequency (bandwidth)

222.15 Explain the reasons why electronic amplifiers may be used with other types of power amplifier, eg hydraulic and pneumatic, to form a hybrid system.
Reasons: electronic amplifiers provide high gain at low cost, but have low output power

222.16 Describe briefly the characteristics of a range of electric motors used in industrial control systems.
Motors: dc motors (including brushless permanent magnet types), ac motors, stepper motors

Feedback and performance criteria

222.18 Define the following terms relating to factors influencing the performance criteria of control systems.
Terms: coulomb friction, stiction, viscous friction, linear and angular systems inertia.

222.19 Describe the effect of a gearbox on the effective inertia and viscous friction.

222.20 Describe the effect of gear backlash in a control system.

222.21 Derive differential equations for speed and position control systems where the motor torque is proportional to the error signal.
Equations: linear first and second order

222.22 Sketch a graph showing the response of the system in 222.21 to a step input.

222.23 Identify from the graph in 222.22, the defining features of the system response.
Features: overshoot, period of damped oscillation, time constant, settling time

222.24 Calculate, from the equations derived in 222.21, the undamped natural frequency and damping ratio.

222.25 Define ‘system type number’ and explain how it can be used to calculate the damping ratio of a system from test results.

222.26 Calculate the steady state error in simple closed loop control systems from given practical data.
Systems: speed control, position control

Frequency response and system testing

222.27 Explain that although practical input signals applied to control systems during normal operation are not normally pure sinewaves, it is a very useful signal for test purposes since it contains one fundamental frequency only.

222.28 Explain that a sinusoidal signal can be represented in mathematical form as $v = V(\cos\theta + j\sin\theta)$ or $v = V(\sin\omega t + \phi)$, where V is the amplitude, ω is the angular frequency in radians, t is the time in seconds and ϕ is the phase angle.

222.29 State that the transfer function of a first order system can be written in terms of operator $j\omega$ as $G(j\omega) = 1/(1+j\omega T)$ where T is the time constant of the system in seconds.

222.30 State that the magnitude of $G(j\omega) = 1/(1+\omega^2 T^2)^{\frac{1}{2}}$ and $\tan\phi = -\omega T$ is a convenient means of relating the sinewave response of the system to parameters of the practical system, ie the forward ratio and time constant of the practical system.

222.31 State that the transfer function of a second order system can be written in terms of operator $j\omega$ as $G(j\omega) = [1 - (\omega/\omega_n)^2) - j2\zeta(\omega/\omega_n)$ where ω_n is the natural angular frequency and ζ is the damping ratio.

222.32 State that for a second order system, the magnitude of $G(j\omega)$ is given by: $1/\{[1-(\omega/\omega_n)^2]^2 + [2\zeta(\omega/\omega_n)]^2\}$, and for the phase angle, $\tan\phi = [2\zeta(\omega/\omega_n)] / [1-(\omega/\omega_n)^2]$

222.33 Perform calculations to determine the forward transfer ratios and phase angles of first and second order systems at given sinewave input frequencies using typical practical data for the system parameters.

222.34 Plot graphs of the results of magnitude in dB and phase angle against log frequency from the calculations in 222.33.

222.35 Explain that the graphs plotted in 222.34 are known as Bode diagrams and show that they can be constructed from a series of straight line approximation.

222.36 Construct Bode diagrams (plots) using typical data for practical first and second order systems.

222.37 Describe test methods for obtaining practical results of open and closed loop frequency response of a control system.

222.38 Describe the use of standard test equipment for the test method described in 222.37.
Equipment: low frequency oscillator, variable phase oscillator, phase metre, transfer function analyser

System stability

222.39 Explain that for a closed loop system to be stable, the open loop gain of the system must be less than unity when the phase angle is -180° and this leads to the use of gain and phase margins to determine the degree of stability of a practical system.

222.40 Define ‘gain’ and ‘phase’ margins as the magnitude of the gain and phase respectively at the frequency where the gain magnitude reaches unity (the gain cross over).

222.41 Determine the values of gain and phase margins from Bode plots obtained from practical stable systems.

Nyquist diagrams

222.42 Explain that mathematical expressions such as $G(j\omega) = 1/(1 + j\omega T)$ where T is the time constant of the system in seconds can also be represented in the form of a single polar plot, (magnitude in dB for each phase angle), known as a Nyquist diagram.

222.43 Show by means of a Nyquist diagram that the path of the locus, indicating the magnitude and phase angle of an open loop response, as frequency increases, can be used to indicate the closed loop system stability, ie gain and phase margins.

222.44 Draw Nyquist plots of the open loop frequency response of control systems from typical data and determine if the system is stable and the respective magnitudes of the gain and phase margins.

Use of controllers and compensation techniques

222.45 Explain that the stability of a control system can be improved by changing its frequency response to increase the gain and phase margins.

222.46 Describe, with the aid of diagrams, methods of changing the frequency response of a control system by introducing velocity feedback, transient velocity feedback and lead or lag compensating networks.

222.47 Identify, with the aid of circuit diagrams, resistance-capacitance networks to provide compensation as in 222.46.

222.48 Show, using Bode and Nyquist diagrams, the effects of frequency compensation on the open loop response of control systems.

Process control

222.49 Explain the terms associated with process control plant.
Terms: set point, deviation, offset, proportional band, transport delay

222.50 Explain that control systems operate in either one or two modes.
Modes: continuous (where the control has uninterrupted inputs and outputs), discrete (where the control process involves a number of discrete, or timed events)

222.51 Explain how the performance of a process control can be improved by the use of controllers operating in a variety of modes.
Modes: two-step, an error activated switch, proportional mode (P) where the control action is proportional to the error, derivative mode (D) where the controlling action is proportional to the rate at which the error is changing, integral mode (I) where the control action continues as long as the error persists

222.52 Sketch graphs to show the response of a system to a step input for various control actions.
Control actions: proportional plus derivative, proportional plus integral, three term control, (a combination of P, I and D)

Digital systems

222.53 Explain how open and closed loop control systems can incorporate signal sampling rather than continuous control, thus providing a means of controlling a process by means of digital computers with suitable interfacing, eg digital to analogue and analogue to digital converters.

222.54 Describe with the aid of block diagrams, the operation of computer controlled systems.
Systems: control of position and speed, security and alarm, air conditioning, vehicle engine management

222.55 Describe, for each of the systems in 222.54, the types of sensors and actuators required.

222.56 Explain that signal conditioning and correction in a digitally controlled system can be implemented using either hardware or software methods, and that software methods are likely to provide greater flexibility.

Programmable logic controllers (PLC)

222.57 Identify using manufacturers' data the operational characteristics of typical industrial programmable logic controllers and their power requirement.
Programmable logic controllers: modular, rack-mounted, stand-alone
Operational characteristics: memory size, speed of operation, number and type of input/outputs

222.58 State the various types of transducers (sensors) and actuators commonly used with industrial PLC systems.
Transducers (sensors): mechanically operated switches, optical sensors, electro-magnetic sensors
Actuators: motors, relays and contactors, solenoids

222.59 Sketch a simple PLC block diagram consisting of input port, image and main memory, central processing unit (CPU), output port and buses, and explain the overall operation.

222.60 Explain how a range of logic functions can be generated using relay switching.
Range: AND, OR, XOR, NAND, NOR

222.61 Explain the process of scanning inputs via image memory, monitoring logic conditions and updating outputs.

222.62 Define the scan rate in terms of bytes/second and explain that scan rate is determined by clock frequency and size of memory.

222.63 Explain that phasing errors occur when an input port changes its state twice before the input image memory is updated.

222.64 Explain the need for interfacing circuits and describe the different types of I/O ports available for PLC interfacing.
Input ports: opto-isolated digital
Output ports: relay, transistor, analogue, communication

222.65 Describe the protocols used in signal communication.
Protocols: RS232, RS422, IEE488, 20mA

222.66 Describe the practical implementation of communication links.
Links: twisted pair, coaxial, fibre optic

222.67 Define the response time of a PLC as the delay between an input being turned on and an output changing state and explain the causes of delay.
Causes: mechanical response of output device, electrical response of input device, scan update of image memory

222.68 Explain with the aid of block diagrams the use of A/D and D/A converters in PLC systems.

222.69 State typical values of industry standard analogue voltage and current input/output signals, eg 5V for digital and analogue systems, 0-10V for analogue, 4-20 mA for current output.

222.70 Define the term 'resolution' as applied to D/A and A/D converters and describe the relationship between analogue inputs/outputs and word length eg 8 bit, 12 bit and 16 bit.

222.71 Express numbers using various number systems.
Systems: binary, hexadecimal, BCD

222.72 Describe how bipolar voltages can be converted to unipolar voltages using a summing amplifier (opamp).

Applications and programming

222.73 Describe simple industrial applications of PLCs.
Applications: on/off switching, temperature control, motor speed control, conveyor belt sequencing operations

222.74 Describe with the aid of block diagrams the type of sensors (transducers) and actuators used in given applications.
Applications: on/off switching, temperature control, motor speed control, conveyor belt sequencing operations

222.75 Write programs using flow charts and recognised programming methods, eg ladder diagrams, to perform simple operations.
Operations: logic control, on/off delays, timing, sequencing, counting

Associated mathematics

This section of the syllabus is intended as a guide to the mathematics that candidates are likely to find helpful in carrying out practical calculations arising from the topics in the main body of this unit.

Exponential functions

222.76 Solve equations involving exponential functions arising from electrical problems.
Equations:
$i = I(1 - e^{-t/CR})$, $V = E(1 - e^{-tR/L})$ for electrical circuits.

Complex numbers

222.77 Represent ac quantities using operator jw.

222.78 Perform addition, subtraction, multiplication and division of complex numbers.

222.79 Use polar form in calculations involving jw.

222.80 Convert polar to cartesian form and cartesian to polar form.

222.81 Solve series and parallel ac linear circuit problems.

222.82 Solve problems involving amplitude and phase shift in simple RC networks.

Differential equations

222.83 Apply simple modelling techniques to represent the performance of mechanical and electrical systems based on differential equations.
Systems: electrical L, C and R series and parallel circuits, mechanical spring mass and damper systems, closed loop position and speed control systems

222.84 Determine transient and steady state solutions of first and second order differential equations arising from 222.83.

Laplace transforms

222.85 Explain the general use of Laplace transforms and their application to the solution of electrical and electronic circuit problems.

222.86 Explain that in the s-domain, a transfer function of a network is given by:
$T_{(s)}$ = (Laplace transform of output)/(Laplace transform of input)

222.87 Describe the use of Laplace transform tables to obtain the Laplace transforms of unit amplitude signals which are functions of time.
Signals: impulse, step, ramp, exponential growth and decay, sinewave, cosinewave.

222.88 State the basic rules involved in working with Laplace transforms.
Rules: if a function is multiplied by a constant, the Laplace transform is multiplied by the same constant; if an equation includes a sum of separate quantities, the Laplace transform of the equation is the sum of the separate Laplace transforms; assuming zero initial conditions, the Laplace transform of a first derivative of a function f (t) is s F(s); assuming zero initial conditions, the Laplace transform of a second derivative of a function f (t) is s^2F (s); the Laplace transform of an integral of a function f (t) is 1/s [F(s)]

222.89 Explain that when algebraic manipulations have taken place in the s-domain, the outcome can be transformed back to the time domain using Laplace transform tables in the inverse manner.

222.90 Use operator 's' in place of jv to provide simple transfer functions and Laplace transforms to obtain steady state and transient solutions to simple linear circuit and system problems for a range of small-signal input functions.
Input functions: step, ramp, exponential, sinewave

222.91 Use Laplace transforms to solve network problems arising from electrical system models in 222.83.

Graphical representation

222.92 Calculate voltage, current and power ratios in dB and represent the results in graphical form by plotting the results against frequency.

222.93 Calculate phase shift at various frequencies and plot phase/log frequency along with the results in 222.92 to form a Bode diagram.

222.94 Use the results from 222.92 to show that a polar plot (Nyquist diagram) can be used as an alternative form of plotting both gain and phase shift on a single diagram.

222.95 Use Bode and Nyquist diagrams of open loop response of closed loop control systems to solve problems relating to closed loop stability.

Test specification for written paper Control Systems and Applications (8030-23-222)

This is a written examination paper lasting three hours with ten questions. Candidates must answer **all** ten questions.

The examination paper will cover the knowledge specifications:

Topic	Approximate % examination weighting
Control principles	10
Sensors (transducers)	10
Amplifiers and actuators	10
Feedback and performance criteria Frequency response and system testing System stability Nyquist diagrams Use of controllers and compensation techniques	40
Process control Digital systems Programmable logic controllers (PLC) Applications and programming	30

223 Distribution and utilisation of electrical energy

Introduction

Many industrial processes depend on the conversion of electrical energy into motive power, heat and light. This unit is concerned with the fundamental engineering principles which need to be understood to ensure that electrical installations are correctly planned, constructed and maintained.

Knowledge requirements

On completion of this unit and as a result of instruction and practical activities, the candidate should be able to:

Distribution systems

223.1 Describe and compare low voltage (LV) distribution wiring systems.
Wiring systems: sheathed and armoured cables, mineral insulated metal sheathed cables, conduit, trunking and cable ducts, bus-bar

223.2 Describe the factors relating to high voltage (HV), 11kV/400V, substation siting, planning and plant layout.
Factors: economic considerations, safety, ease of maintenance, servicing, operational requirements

223.3 Sketch typical arrangements of switchgear and protection equipment for small industrial and commercial installations.

223.4 Select suitable equipment relating to the planning of an electrical installation with regard to the requirements of the specification.
Equipment: cables, switchgear, protective devices
Requirements: load, diversity, possible future modifications

223.5 Sketch diagrams of metering connections of single and three phase energy meters and describe the applications of the meters in low voltage (LV) and high voltage (HV) systems.

223.6 Determine suitable cable sizes required in an installation to comply with the requirements of standard regulations for the requirements of electrical installations.
Requirements: correction factors, volt drop, current, earth-loop impedance, diversity

223.7 Explain the effects of harmonics produced by electronic switching devices on the power supply and distribution networks.

Protection systems and devices

223.8 Explain the terms used in connection with protective systems applied to electrical equipment.
Terms: stability, sensitivity, stability ratio, discrimination

223.9 Compare the conflicting factors of stability and discrimination and explain how a workable compromise is reached.

223.10 Describe a range of protection relays and their applications.
Range: overcurrent, earth fault, inverse definite minimum time (IDMT), directional, differential, Buchholz

223.11 Describe the precautions to be taken when working on protection systems operated by current transformers (CT).
Precautions: short circuit CT secondary, isolate CT primary

223.12 Calculate IDMT relay settings for specified conditions using manufacturer's characteristics.

223.13 Describe the main constructional and operational characteristics of metal clad indoor and outdoor switchgear and select the most suitable type for a particular application.
Switchgear: circuit breaker, oil switch, switch-fuse, isolator (disconnector)

223.14 Describe, with the aid of sketches, the arrangements of contacts and principles of arc control in types of circuit breakers.
Circuit breakers: air blast, air break, oil, vacuum, SF6

223.15 Explain the meaning of the terms 'recovery voltage' and 'restriking voltage' and the process of interrupting a loaded circuit under various conditions.

223.16 Describe the principle and methods of earthing low voltage systems.
Systems: TN-S, TN-C-S, TT, TN-C, IT

223.17 Describe the principle and methods of earthing high voltage equipment.
Equipment: switchgear, ground and pole mounted transformers, disconnector switches, surge arrestors

223.18 Explain the importance of maintaining separation between HV and LV earthing systems and the conditions under which they may be combined.

223.19 Describe how the earth electrode resistance may be measured using earth resistance tester.

223.20 Explain the principle of operation of current operated residual current devices (RCD).

223.21 Describe and compare methods of excess current protection in a range of circuits.
Circuits: main, sub-main, final sub-circuits

223.22 Describe the factors to be considered when deciding on the need for lightning protection of buildings.
Factors: height and area of building, environment, type of construction

223.23 Describe the construction and design, including the materials, of the main parts of a lightning protection system.
Main Parts: air termination network, down conductors, earth termination

Machines

223.24 Explain the methods of starting induction and synchronous motors.
Methods: direct on line, auto transformer, star delta starter, rotor resistance control, thyristor control

223.25 Describe, with the aid of circuit diagrams, methods controlling the speed of ac motors.
Methods: rotor resistance control, pole changing, supply frequency and voltage control using thyristors

223.26 Describe, with the aid of circuit diagrams, methods of starting dc motors.
Methods: face plate starters, electronic (thyristor) starter systems

223.27 Describe, with the aid of circuit diagrams, methods of speed control of dc motors.
Methods: field control, armature voltage control, electronic converters and chopper drives

223.28 Describe the applications and advantages and disadvantages of a range of ac and dc motors.
Range: synchronous, single and three phase induction, series, shunt and compound wound

223.29 Define the terms associated with machine rating.
Terms: continuous, short time, rms

223.30 Calculate, for a given duty cycle, the intermittent and continuous rating of a machine.

223.31 Calculate the motor power and torque required for stated purposes.

223.32 Select, using manufacturer's data, a correctly rated suitable type of electric motor and the appropriate control gear for a range of applications taking into account a range of factors.
Applications: pumps, compressors, machine tools, fans, generating plant, lifts and traction applications
Factors: supply voltage, load characteristics, prime and running costs, efficiency, power factor, load factor, type of enclosure, maintenance

223.33 Sketch schematic diagrams of power control circuits for the sequence control of electric motors for specified conditions and applications eg in industrial processing plant.

223.34 Explain why motor controllers incorporate a range of protection control.
Protection: overload, loss of supply, overspeed, short circuit, excessive temperature

223.35 Explain, with the aid of diagrams, the principles, operation and applications of a range of protection devices.
Protection devices: electromagnetic, thermal, bimetallic, thermocouple, fuses, relays, current transformers

223.36 Explain why a time delay may be an essential feature of overload protection.

223.37 Describe the principle of operation of a permanent magnet stepper motor and state typical applications eg table drives in computer controlled machine tools.

223.38 Describe the operating features of a stepper motor.
Feature: shaft rotates in either direction in discrete steps, shaft position can be identified, requires some form of electronic drive/control, power and torque depends on the size of the machine and the capability of the drive circuit

Heating, refrigeration and air-conditioning

223.39 Describe methods of space heating.
Methods: block storage, radiation, convection, underfloor systems

223.40 Describe electrical systems for heating water and producing steam using three phase electrode boilers.

223.41 Design a basic heating system taking account of heat losses, air changes and additional heat sources.

223.42 Explain, with the aid of a block diagram of the basic components, the principle of operation of refrigeration systems.
Components: condenser, evaporator, capillary tube, compressor, refrigerant

223.43 Explain, with the aid of a block diagram of the basic components, the principle of operation of air conditioning systems.
Components: Heating and cooling coils, humidifier, expansion valve, fans and filters, refrigerant

223.44 Describe electrical machines and control equipment appropriate for the installation of refrigeration and air conditioning systems.
Equipment: motors, starters, electronic control (including microprocessor control) relays, sensors (transducers), switch gear, compressors and fan drives

223.45 Explain, with the aid of a block diagram of the basic components, the principles of operation of heat pumps.
Components: condenser coil, evaporator coil, expansion valve, reversing valve, fans, refrigerant

223.46 Describe the operation of heat pumps in a range of applications.
Applications: heat recovery, moisture removal (dehumidification), air conditioning

Industrial processes

223.47 Sketch a diagram of the electromagnetic spectrum showing the widely used frequency ranges.
Frequency ranges: radio frequency, microwaves, infra red, ultra-violet, X-rays

223.48 Describe electroheating processes and state typical applications.
Processes: resistance, induction, dielectric and microwave, radiant
Typical applications: heating and cooking, metal hardening and annealing, metal joining, fabric drying, welding of thermo-plastics

223.49 Describe the principle of operation of types of electric furnace for melting and heat treating metals.
Types: resistance (heat treatment), induction (melting)

223.50 Describe the range of equipment used to generate the high power frequency signals used in induction, dielectric and microwave systems.
Equipment: fixed and variable frequency generators incorporating large thermionic valves, klystron and magnetron devices, associated control circuitry

223.51 Describe briefly ac and dc electric welding processes.
Welding Processes: arc, resistance, radiation, laser, electron beam

223.52 Describe the electrical equipment associated with electric welding processes.
Equipment: transformers, inductive reactors, capacitors, relays, trip switches, spark gaps

223.53 Explain the principles and advantages of electrostatic paint spraying.

Illumination

223.54 Explain a range of terms relating to light sources.
Terms: reflection, diffusion, refraction, shadow, glare, luminosity (brightness)

223.55 Define a range of terms relating to illumination and in each case, state the appropriate units.
Terms: candela, lumen, luminous intensity, apostilb, luminous flux, luminance, illuminance, lux, maintenance factor, utilisation factor

223.56 Describe on-site measurement of illuminance with reference to desirable levels.

223.57 Compare polar curves, using manufacturer's data, for types of luminaries.
Luminaries/lamps: tungsten filament, reflector lamps, tungsten halogen, discharge, fluorescent tubes

223.58 Calculate, using the lumen method, the number of luminaries required for internal and external lighting schemes, taking account of the siting and type of luminaire.

Testing

223.59 Describe methods and equipment used for the following electrical tests.
Tests: continuity of protective conductor, ring circuit continuity, insulation resistance, polarity, earthloop impedance, residual current devices

223.60 Explain the following terms relating to high voltage (HV) testing.
Terms: withstand, breakdown, puncture, flashover, tracking

223.61 Describe the methods and test equipment required for HV insulation tests on a range of equipment.
Equipment: motors, cables, switchgear, transformers

223.62 Explain the reasons for and the methods used to discharge equipment on completion of high voltage tests.
Methods: resistance discharge stick, earthing switch

Test specification for written paper Distribution and Utilisation of Electrical Energy

This is a written examination paper lasting three hours and comprising ten questions. Candidates must answer **all** ten questions.

The examination paper will cover the knowledge specifications:

Topic	Approximate % examination weighting
Distribution Systems	14
Protection Systems and Devices	14
Machines	24
Heating, Refrigeration and Air-Conditioning	14
Industrial Processes	10
Illumination	14
Testing	10

224 Generation and supply of electrical energy

Introduction

A major proportion of industry, commercial businesses and domestic homes depend on a reliable supply of electrical energy into which can be converted into motive power, heat and light. This unit is concerned with the fundamental engineering principles relating to the generation of electricity and its transmission on overhead and underground cables supplied via transformers.

Knowledge requirements

On completion of this unit and as a result of instruction and practical activities, the candidate should be able to:

Generating stations

224.1 Explain a 'load duration curve' and construct typical curves from given data relating to a supply situation.

224.2 Describe the general economic considerations relating to generating stations and the distribution of power over the operating range from base load to peak load.
Economic considerations: power station efficiency, cost per unit supplied, load cycle and start up time, transmission losses, load balancing, security of supply.

224.3 Describe the factors which determine the choice of energy source and the appropriate form of construction for a power station in given situations.
Factors: capital cost, running cost, load factor, geographical and environmental siting requirements.

224.4 Describe the advantages and disadvantages of conventional types of fuel and other renewable energy sources for power generation taking into account the factors which influence the choice of energy source.
Types of Fuel: coal, oil, gas, hydro, nuclear
Renewable energy sources: wind, geothermal, solar, tide and wave, gas from waste burning and land fill

224.5 Calculate the load factor and diversity factor from load curves and estimate the effect of each factor on the overall cost of generation.

224.6 Determine a suitable tariff to cover the standing and running costs of a given power station.

224.7 Compare the use of a public supply with the use of an on-site generating plant taking into account the various factors which may influence the choice of supply.
Factors: convenience, economic, continuity of supply, use of waste heat

224.8 Calculate the output from, and the efficiency of, a hydroelectric power station from given data.

224.9 Describe the basic principles of alternative methods of power generation.
Alternative methods: wind power, solar, geothermal, tide ebb and flow, river converters, use of gas and heat from waste disposal

224.10 Describe the benefits of heat recovery in combined heat and power systems (CHP).

224.11 Calculate the overall efficiency of systems employing combined heat and power (topping or tailing economics).

224.12 Explain the benefits and describe the main features of pumped storage schemes.
Features: high and low level water storage, pumps, hydro electric generation

Synchronous generators

224.13 Describe the use of gas and liquid cooling for the stator and rotor of large generators.

224.14 Sketch a phasor diagram for a single generator supplying an isolated load.

224.15 Explain the meaning of 'load angle' and its variation with output power.

224.16 Sketch the operating chart of a generator feeding into a large system, showing the following limiting conditions.
Conditions: stator current, rotor current, power (knar), theoretical stability

224.17 Describe the methods of synchronising a machine with infinite busbars.
Methods: two lamp, synchroscope, synchroniser

224.18 Describe the effect of transient and sub-transient reactances of a generator when it is short circuited.

224.19 Describe, with the aid of a waveform diagram, how a dc transient component (doubling effect) can arise, depending on the instant in the cycle, when a short circuit occurs.

224.20 Calculate the rms value of an asymmetrical short circuit waveform.

Transformers

224.21 Explain, with the aid of diagrams, how transformer windings may be connected in different configurations. Use standard markings to show phase and polarity.
Configurations: star, delta, interconnected star arrangements

224.22 Describe the conditions necessary for the parallel operation of transformers.
Conditions: voltage, phase sequence, phase shift, impedance

224.23 Calculate, from given data, the distribution of load between two transformers operating in parallel.

224.24 Describe the phase groupings of star-star and star-delta connected transformers for the interconnection of various system voltages.
Voltage systems: 132/33kV, 33/11kV, 11kV/415 or equivalents

224.25 Describe the principle and operation of types of manual and automatic tap changing.
Types: off load manual, on load resistance and reactor

224.26 Describe the procedure for testing transformer and switchgear oil.
Tests: moisture, acidity, breakdown voltage

Transmission circuit principles

224.27 Sketch an equivalent circuit of a short transmission line using lumped cable parameters.
Cable parameters: resistance or conductance, inductance, capacitance

224.28 Solve problems, from given data, relating to voltdrop and power loss in short transmission lines.

224.29 Sketch equivalent circuits of three phase transmission lines and determine the ABCD parameters (a_{11}, a_{12}, a_{21}, a_{22})
Circuits: nominal T, nominal π

224.30 Determine the ABCD, or A parameters, from given data and use them to calculate input voltage and current given the load conditions.

224.31 Sketch an equivalent circuit of a transformer supplying a line.

224.32 Calculate, from given data, the share of the load and voltage drop in parallel connected lines.

224.33 Describe the 'reactive compensation' method of balancing the loading in parallel lines.

224.34 Calculate symmetrical fault currents using star-delta transformations where appropriate.

224.35 Calculate asymmetrical fault currents using symmetrical components.

224.36 Describe, with the aid of a circuit diagram, how symmetrical components of current can be measured.

Overhead lines

224.37 Describe the factors which have to be taken into account in fixing the route of an overhead line.
Factors: terrain and type of soil, amenities, safety, interference with communication circuits

224.38 Describe the use of design aids to determine the sag and tension in overhead lines.
Design aids: charts, templates, computer programs

224.39 Describe the construction used for a range of overhead lines.
Lines: copper, aluminium, aluminium alloy, aluminium conductor steel reinforced (ACSR), Aerial Bundled Conductor (ABC)

224.40 Compare the suitability of different types of conductor, in various applications, on the basis of their properties.
Properties: electrical conductivity, mechanical strength, corrosion resistance

224.41 Describe the important physical factors to be considered in overhead line construction.
Physical factors: conductor separation, ground clearance, wind and ice loading, environment

224.42 Describe the construction of suspension, pin and post type insulators.

224.43 Describe the effects of moisture and pollution on the breakdown voltage of insulators and explain how good design can reduce these effects.

224.44 Explain why insulation stress is a maximum adjacent to the line and how the stress may be more evenly distributed by grading or by rings.

224.45 Calculate the voltage distribution across an insulator string and hence determine the string efficiency.

224.46 Explain the basic principles and operation of moving coil and induction regulators.

Underground cables

224.47 Describe the construction of various types of cable.
Cable types: solid, gas-filled, oil-filled, screened, polymeric

224.48 Describe for different types of cable, an appropriate method of cable laying and jointing.
Cable types: solid, gas-filled, oil-filled, screened, polymeric

224.49 Compare the applications of different types of cable on the basis of the conditions
Cable types: solid, gas-filled, oil-filled, screened, polymeric
Conditions: voltage range, temperature range, grouping, ground conditions

224.50 Sketch a diagram showing the access points, joints and feed points for oil or gas filled cables.

224.51 Describe tests to locate faults and for the condition of the insulation.
Tests: for fault location: Loop, capacitance, pulse echo
For insulation condition: ac and dc insulation testers, loss angle test

224.52 Calculate the position of a fault from test data.

224.53 Explain 'loss angle' and its importance in assessing the quality of cable insulation.

224.54 Describe the effects of voids in cable insulation and the mechanism of ionisation breakdown.

224.55 Calculate the capacitance of a single core, or H type, cable using the formula $C = 2\pi\epsilon_0\epsilon_r / (\ln R/r)$ F/m

224.56 Calculate the insulation resistance of single core cable using the formula $R = r / 2\pi (\ln R/r)\ \Omega m$

Substations
224.57 Explain the reasons for different voltage levels for transmission and distribution.

224.58 Explain how the electrical layout of substations is influenced by the security of supply and maintenance requirements.

224.59 Describe the electrical equipment found in typical substations.
Equipment: surge diverters, surge absorbers, switchgear, transformers, tap changers, protection equipment

224.60 Explain the necessity for co-ordinating insulation levels with the use of surge absorbers and diverters.

224.61 Describe the cause and effects of corona on a transmission system and how these affects can be reduced.

224.62 Calculate voltages on a system due to switching surges.

224.63 Calculate the rate of rise of restriking voltage across a circuit breaker interrupting a short circuit at the terminals of a synchronous generator.

Operational safety
224.64 Explain the reasons for safe systems and safe working control.
Reasons: safety of staff and members of the public, safety of equipment, legal requirements

224.65 Describe typical procedures for making LV and HV systems safe for work and the importance of effective communications.
Procedures: system control, operation requirements, switching programmes, safety documentation

224.66 Describe safety procedures for isolating, earthing and testing LV and HV apparatus.
Apparatus: switchgear, transformers, cables, lines

224.67 Describe safe working practices for working on live LV apparatus.
Practices: approved procedures, personal protective equipment, insulated tools for work on LV cables and lines

224.68 State the precautions to be taken when working on remotely or automatically controlled apparatus and auto-reclose systems.
Precautions: safety procedures, isolation of remote/automatic features, circuit earthing

Economics
224.69 Explain the various factors involved in an economic system of transmission and distribution.
Factors: minimise conductor size, route length, peak loads, conductor losses, load imbalance

224.70 State Kelvin's law and apply it to the calculation of the most economical cross section of conductor for cables and transmission lines.

224.71 Explain why a high power factor is encouraged in tariff structure.

224.72 Calculate the most economical power factor based on the unit cost of phase advancing plant and maximum demand tariff charges.

224.73 Calculate, from given data, the all-day efficiency of transformers.

Test specification for written paper Generation and Supply of Electrical Energy (8030-23-224)

This is a written examination paper lasting three hours and comprising ten questions. Candidates must answer **all** ten questions.

The examination paper will cover the knowledge specifications:

Topic	**Approximate % examination weighting**
Generating Stations	12
Synchronous Generators	12
Transformers	10
Transmission circuit principles	12
Overhead Lines	12
Underground Cables	12
Substations	10
Operational Safety	10
Economics	10

225 Micro-electronic circuits and systems

Introduction

This unit provides further study of the application of electronics. It includes a range of topics covering devices, circuits and systems with appropriate industrial applications. The treatment of the topics include both descriptive and mathematical calculations to a level where students can produce practical circuit and system designs.

Knowledge requirements

Instructors must ensure that candidates are able to:

Information transmission, signals and noise

225.1 Describe the baseband frequencies arising from a range of signal applications.
Applications: Audio systems, radio broadcasting, cellular phones, two way radio, TV transmission, microwave transmission, radar, fibre optic systems

225.2 Define various types of signal encountered in electronic systems.
Signals: analogue, digital/pulse, video

225.3 Define modulation as applied to communication systems.

225.4 Describe the various types of modulation used in communication systems.
Types: amplitude, angle (frequency and phase), pulse (position, width and code)

225.5 Calculate the various parameters associated with amplitude and angle modulated signals.
Parameters: modulation factor, modulation index and deviation, bandwidth, sidebands

225.6 Explain how noise is a limiting factor in communicating systems and the importance of signal to noise ratio.

225.7 Calculate signal to noise ratio in dB from given data.

Amplifiers

225.8 Explain briefly the terms associated with various types of amplifier.
Terms: small-signal, large signal, negative feedback, operational, audio frequency, video, radio frequency, tuned frequency

225.9 Describe, with the aid of circuit diagrams, the types of negative feedback encountered in amplifier circuits.
Types: current and voltage, series and parallel connected

225.10 Describe the features associated with the application of negative feedback.
Features: loss of gain, modification of input and output impedance, reduction in distortion, improvement in gain stability, increase in bandwidth

225.11 Perform calculations relating to negative feedback amplifiers.
Calculations: voltage gain, bandwidth, input and output impedances

225.12 Describe, with the aid of circuit diagrams, the operation of different types of amplifier.
Types: single and two stage small signal, large signal output stages (class A, B and class AB complementary symmetry circuits), tuned frequency, operational (including inverting and non inverting ac and dc coupled), integrated circuit amplifiers, eg power amplifiers

225.13 Perform calculations relating to the performance of the amplifiers listed in 225.12.
Calculations: voltage and current gains, ac and dc power, conversion efficiency, tuned frequency – 3dB frequencies and bandwidth

225.14 Describe the causes of signal distortion in amplifiers.
Causes: amplitude limiting, non-linearity, insufficient bandwidth, slew rate limiting

225.15 Explain the need for using heat sinks with power amplifiers and perform simple calculations.
Calculations: thermal resistance, temperatures (ambient and junction), heat sink ratings

Oscillators

225.16 Explain the term positive feedback and the conditions for oscillations to be maintained.
Conditions: loop-gain positive and equal to, or greater than, unity

225.17 Describe, with the aid of circuit and waveform diagrams, the operation of types of sinewave oscillators based on discrete device and integrated circuit packages.
Types: audio frequency resistance and capacitance (both Wien bridge and phase shift), tuned frequency (inductance and capacitance and crystal controlled)

225.18 Perform calculations relating to the design and operation of oscillators.
Calculations: loop gain, frequency of oscillation

225.19 Describe, with the aid of circuit and waveform diagrams, the operation of types of relaxation oscillator based on both discrete components and integrated circuit designs.
Types: astable, and monostable multivibrators, blocking

225.20 Perform calculations relating to the performance of relaxation oscillators.
Calculations: frequency of oscillation, pulsewidth

Power supplies

225.21 Explain the need for regulated (stabilised) power supplies in electronic equipment applications.

225.22 Describe, with the aid of circuit diagrams, the operation of basic types of regulator.
Types: shunt, series

225.23 Explain, with the aid of circuit diagrams, how a combination of series and shunt regulators is used to provide the basis for a stabilised power supply and how the system can be improved by the addition of dc amplifiers and negative feedback

225.24 Perform calculations relating to the operation of stabilised power supplies including the applications of commercially available integrated circuit types eg 7812 and 7912.
Calculations: output resistance, regulation, output voltage

225.25 Describe, with the aid of circuit diagrams, the operation of protection circuits in stabilised power supplies.
Circuits: over current, over voltage

225.26 Explain, with the aid of circuit diagrams, the principle of operation of a switched mode dc voltage regulator eg integrated circuit type L296.
Operation: pulse width modulator (PWM) operating at high frequency followed by a smoothing circuit with feedback controlling the pulse width and dc output voltage

225.27 Describe the advantages of switched mode power supplies.
Advantages: greater efficiency, smaller size due to greater efficiency, suitable for high current low voltage supplies

Power control

225.28 Describe the features of a power MOSFET and perform simple calculations of current and voltage levels in dc load control.
Features: high input resistance, low saturation resistance, low saturation voltage, high saturation current

225.29 Describe, with the aid of current/voltage characteristics, the operation of semiconductor power switching devices.
Devices: thyristor, diac, triac, unijunction transistor

225.30 Explain, with the aid of a circuit diagram, the operation of a unijunction transistor relaxation oscillator.

225.31 Describe, with the aid of circuit and waveform diagrams, typical applications of the power switching devices listed in 225.29.
Applications: half bridge and full bridge control of ac motor speed using thyristors, control of ac lighting using a triac

225.32 Describe the use of burst firing, in conjunction with zero crossing triggering, for the control of ac heating loads.

225.33 Perform calculations on power switching applications.
Calculations: rms power with phase control of triacs and thyristors, rms power with burst firing control of heating loads

225.34 Explain methods of commutation and the general operation a dc to ac inverter circuit incorporating pulse oscillators controlling thyristors operating in push-pull.
Methods of commutation: capacitor, resonant

225.35 Describe the process of converting a dc voltage at one level to a dc voltage at a higher level by inverting, transforming and rectifying.

Introduction to microcomputers

225.36 Sketch a block diagram of the major components and interconnecting control and data lines forming a typical microcomputer.
Components: central processing unit (CPU), clock, address decoder, read only memory (ROM), random access memory (RAM), input/output ports

225.37 State the functions of the components and describe the overall operation of the system.
Components: central processing unit (CPU), clock, address decoder, read only memory (ROM), random access memory (RAM), input/output port

225.38 State examples of input and output peripherals.
Examples: lights, printers, motor-drivers and relays, keyboards, switches, transducers (sensors)

225.39 Describe the internal structure (architecture) of a typical 8-bit CPU.
Structure: accumulator, flag register, instruction register, instruction decoder, register array, arithmetic logic unit (ALU), controller with control lines and address and data buffers

225.40 Describe the structure and purpose of the items listed in 225.39.
Structure: accumulator, flag register, instruction register, instruction decoder, register array, arithmetic logic unit (ALU), controller with control lines and address and data buffers

225.41 State the purpose of the instruction set within the CPU.
Purpose: to provide a means of creating (calling-up) specific functions by means of a numerical code

225.42 Describe the nature of common addressing modes within the CPU.

225.43 Describe the nature and state the purpose of the bus structures.
Bus structures: data bus, address bus, control bus

225.44 Explain how peripherals are provided with service on the basis of interrupts which may be generated through either software or hardware methods.

Logic systems

225.45 Describe the range of different codes in general use in logic systems.
Codes: binary, binary coded decimal (BCD), hexadecimal (hex), Grey code

225.46 Perform a range of simple code conversions limited to 8 bit numbers.
Range: binary to BCD, binary to hex, binary to decimal, decimal to hex, hex to decimal, decimal to binary, Grey to binary, binary to Grey

225.47 Define, with the aid of waveform diagrams, logic conventions.
Conventions: positive, negative

225.48 Define terms relating to logic circuit states.
Terms: don't care, can't happen, indeterminate

225.49 Define terms relating to logic systems.
Terms: combinational, sequential

225.50 Define terms relating to logic data forms.
Terms: serial, parallel

225.51 Explain terms relating to logic circuits.
Terms: TTL, CMOS, tristate, open collector, logic levels, noise margins, propagation delays, fan in, fan out

225.52 Describe the features of CMOS circuits compared to TTL types.
Features: requires less power, wider tolerance on supply voltage, logic levels less precise, propagation delays marginally longer, noise margin smaller, lower price

225.53 Describe with the aid of truth tables, the operation of a range of 3-input logic gates.
Gates: AND, OR, NAND, NOR, XOR, XNOR

225.54 Derive, using Boolean algebra, including DeMorgan's rules and/or truth tables, a Boolean expression representing the outputs from a range of combinational logic circuits.
Range: not more than five input variables and a maximum of four levels of gating

225.55 Use Karnaugh mapping techniques, utilising 'don't care' and 'can't happen' situations, where appropriate, to establish practical combinational logic systems in minimal form to implement stated logic specifications.
Systems and specifications: range limited to the conditions stated in 225.54

225.56 Describe typical simple tasks that require sequential logic circuits.
Tasks: serial to parallel conversion, pulse counting, shift registers

225.57 Explain the need for a clock in sequential logic circuits and understand how circuits can be switched on either the leading or trailing edge or a clock pulse.

225.58 Describe, with the aid of circuit and waveform diagrams and/or truth tables, the operation of a range of bistable circuits (Flip-flops).
Circuits: S-R, J-K, D-type

225.59 Identify the purpose of additional facilities available with integrated circuit versions of bistables.
Facilities: input gating, set, reset, clear, enable, disable

225.60 Describe, with the aid of circuit diagrams and truth tables, how clocked bistables may be used as counting elements in both synchronous and asynchronous (ripple through) counters.
Counters: four stage binary, four stage ring and crossed ring (Johnson counter)

225.61 Describe the operation of shift registers in practical applications relating to conversion of data.
Applications: serial to parallel, parallel to serial

225.62 Define a multiplexer integrated circuit as a digitally controlled sequence or scanning switch that allows any one of a number of input signals to be connected to a single output, according to the digital control signals applied.

225.63 Define a demultiplexer as the opposite of a multiplexer ie it has a single input that can be connected to any one of a number of outputs according to the control signal applied.

Display devices

225.64 Describe with the aid of circuit diagrams how light emitting diodes (LEDs) may be driven using standard circuit techniques.
Circuits: current sinking, or current sourcing, with current limiting resistors

225.65 Explain how the overall power requirements of LED displays may be reduced using multiplexing techniques.

225.66 Describe, with the aid of diagrams, the construction and operation of liquid crystal displays (LCDs).

225.67 Describe the features of LCDs compared to LEDs.
Features: low current, LCDs do not generate light, requires ac squarewave drive to extend life

225.68 Describe the construction and operating of an LED Seven Segment Display with a suitable decoder/driver, eg type 4511.

225.69 Perform calculations to determine suitable component values in LED and LCD output display driver circuits.

A-d and d-a conversion

225.70 Explain the terms associated with the electronic converters.
Terms: quantisation error, electronic error, resolution, offset, settling time, analogue output resistance, linearity, accuracy

225.71 Describe, with the aid of circuit diagrams, the operation of typical integrated circuit based ADCs.
Circuits: counter-ramp, successive approximations, parallel comparator (Flash type)

225.72 Compare conversion times for the circuits listed in 225.71.
Times: counter-ramp 2^n x clock pulse period, successive approximations (n+1) x clock pulse period where n = number of bits. Flash converter depends on the propagation time of the encoders (very fast).

225.73 Describe, with the aid of circuit diagrams, the operations of typical DAC circuits.
Circuits: weighted resistor, R-2R ladder network

225.74 Explain the advantages of the R-2R network method.
Advantages: involves only two resistor values, greater accuracy for the larger number of bits

225.75 Perform calculations on ADCs and DACs.
Calculations: conversion times, accuracies/errors, circuit component values

225.76 Explain the reason for the use of sample and hold circuits with ADCs.
Reason: holds input signal voltage at the sampled value for the period of conversion

225.77 Define the terms used in connection with sample and hold circuits.
Terms: acquisition time, aperture time, droop

225.78 Use manufacturer's data to obtain values of the terms listed in 225.77 for practical circuits.

Test specification for written paper Micro-electronic Circuits and Systems (8030-23-225)

This is a written examination paper lasting three hours with ten questions. Candidates must attempt **all** ten questions.

The examination paper will cover the knowledge specifications:

Topic	Approximate % examination weighting
Information transmission, signals and noise	10
Amplifiers	10
Oscillators	10
Power supplies	10
Power control	10
Introduction to Microcomputers	10
Logic Systems	20
Display Devices	10
A-D and D-A Conversion	10

226 Electrical plant and equipment

Introduction

This unit is intended for candidates who are involved with industrial plant. It provides a detailed approach to the construction, design and performance characteristics and industrial applications of electric motors and transformers. Calculations relating to design and performance of plant are included in the relevant sections.

Knowledge requirements

On completion of this unit and as a result of instruction and practical activities, the candidate should be able to:

General machine theory

226.1 Describe the types of materials, used in the manufacture of electrical machines for insulation, electrical conduction and magnetic circuits.
Materials: Insulation varnished cotton, paper, enamel
Conduction copper, aluminium
Magnetic laminated high resistivity silicon steel

226.2 Describe the properties/characteristics and operational limits of the materials used in the manufacture of electrical machines and explain why the materials are particularly suited to this application.

226.3 Describe with the aid of sketches typical insulation arrangements for electrical machines.
Machines: static, rotating

226.4 Describe the various forms of loss which occur in an electrical machine.
Forms: copper and iron losses, windage, friction

226.5 Explain the need for cooling and describe typical methods of cooling used with static and rotating machines.
Methods: natural air, forced air, oil, heat exchangers

226.6 Describe the factors which affect steady state temperature rise in electrical machines.
Factors: field and armature losses, load power, methods of cooling

226.7 Calculate temperature rise and decay in machines using formulae and given data.

226.8 Sketch typical machine temperature curves from calculated data.

226.9 Define terms used in connection with machine ratings.
Terms: continuous, short time, rms

226.10 Solve problems relating to machine ratings from given data.

226.11 Select, using manufacturer's data, a class of machine to suit specified ambient conditions.

Transformers

226.12 Describe types of construction of transformers.
Types: core, shell, Berry

226.13 Describe the types of winding used in transformer construction.
Windings: disc, helical, layer, sandwich

226.14 Describe the standard markings for identification and markings used for transformers.

226.15 Sketch diagrams of winding arrangements and standard connections of transformers.
Connections: star, delta, inter star

226.16 Sketch phasor diagrams and explain their relation to the clock reference system for standard transformer connections.
Connections: star, delta, inter star

226.17 State the conditions necessary for the parallel operation of transformers.
Conditions: same voltage ratio, same phase displacement, same voltage regulation, similar internal phase relationship between R and X

226.18 Calculate the distribution of load for transformers operating in parallel from given data.

226.19 Explain how the third harmonic content of the magnetising current affects transformer design.

226.20 Explain the need for tertiary windings in transformer construction and design.

226.21 Describe the techniques used for transformer tap changing for different strategies.
Strategies: manual, automatic

226.22 Explain, with the aid of a labelled sketch, the arrangement and connection of transformers for auto-transformer operation indicating the directions of current.

226.23 Describe the applications in which auto-transformers are used.
Applications: induction motor starting, high voltage distribution systems

226.24 Describe the characteristics of transformer used in a range of specialised applications.
Applications: welding, discharge lighting, induction motor starting, isolation, measurements

Synchronous machines

226.25 Describe the construction of synchronous machines
Machines: cylindrical rotor, salient pole

226.26 Describe methods of supplying excitation power to synchronous machines.
Methods: direct coupled ac and dc generators, permanent magnet generators

226.27 Sketch an equivalent circuit of a synchronous machine.

226.28 Perform calculations from given data.
Calculations: excitation , load power, power/load angle relationship
Data: terminal voltage, load current, power factor, excitation current

226.29 Describe the conditions necessary for synchronising an ac generator.

226.30 Describe the synchronisation of an ac machine with a similar machine or an infinite busbar.

226.31 Explain the effects of varying the power input or excitation on a synchronous machine.
Effects: open circuit terminal emf, short current, on load terminal voltage

226.32 Calculate the synchronising power from given data.
Data: open circuit terminal voltage, on load power and power factor, winding resistance, synchronous reactance

226.33 Construct an operating chart for a motor or generator connected to an infinite busbar.

226.34 Indicate on the operating chart and explain the operating limits.

226.35 Explain typical applications for synchronous motors.
Applications: constant speed drives, power factor correction

226.36 Describe methods of starting synchronous motors.
Methods: using a separate motor, starting as an induction motor

226.37 Explain the use of synchronous motors for power factor improvement.

Induction machines

226.38 Describe the construction of types of rotor used in induction motors.
Types: cage, wound

226.39 Sketch an equivalent circuit of an induction motor with the rotor and stator impedances shown in series and explain the associated phasor diagram.

226.40 Perform calculations on induction motors from given data.
Calculations: power factor, rotor losses, power transfer to rotor, output torque, input and output power, efficiency

226.41 Explain why direct on line starting torque and current may not be acceptable.

226.42 Sketch the torque/slip characteristics of an induction motor and explain how the starting conditions may be improved by different types of rotor design.
Designs: wound, double cage

226.43 Describe methods of starting induction motors on reduced voltage.
Methods: star-delta, auto-transformer, soft start (electronic)

226.44 Explain, with the aid of appropriate circuit diagrams, methods of speed control of an induction motor.
Methods: rotor resistance, pole changing, variable frequency and voltage

226.45 Calculate the change of speed due to variation in rotor resistance from given data.

226.46 Describe the construction and principle of operation of different types of single phase induction motors.
Types: split phase, capacitor start

226.47 Describe the construction and principle of operation of a universal motor.

226.48 State typical ratings and describe applications of a range of single phase motors.
Range: split phase, capacitor start, universal

DC machines

226.49 Explain, with the aid of sketches of construction and circuits, the principles of operation of dc motors and generators.

226.50 Sketch typical operating characteristics for a range of dc machines.
Range: shunt, series, compound

226.51 Determine, by graphical means, the stable speed and torque conditions of different types of dc motor for a specified load characteristic and hence calculate the required rating.
Types: shunt, series, compound

226.52 Describe, with the aid of circuit diagrams, how thyristors may be used to provide control of dc motors.
Control: starting, speed control of shunt wound motors

226.53 Explain the necessary precautions which need to be observed when using thyristors in motor control.
Precautions: avoid overload and over voltage, prevent excessive current surges and voltage spikes, avoid transients generated by sudden changes

Protection of machines

226.54 Explain a range of protection requirements of electrical machines.
Requirements: overload, loss of supply, overspeed, short circuit, excessive temperature

226.55 Explain, with the aid of diagrams, the principle of operation of a range of protective devices.
Protective devices: electromagnetic, thermal, bi-metallic, thermocouple

226.56 Explain why time delay may be an essential feature of overload protection.

226.57 Explain, with reasons, which type of device is used in practical situations to provide protection of electrical machines.
Protection: overload, loss of supply, overspeed, short circuit, excessive temperature

Special purpose machines and supplies

226.58 Describe, with the aid of sketches, the principle of operation and construction of a range of special purpose motors.
Motors: stepper, permanent magnet, linear, brushless

226.59 Describe typical applications of special purpose motors.
Applications: computer controlled systems, low power d.c. control, traction systems, very high speed low friction applications

226.60 Describe the need for standby supplies and give typical applications.
Need: maintenance of supplies during critical industrial processes, safety considerations
Applications: hospital supplies, computer systems, factory processes

226.61 Describe, with the aid of diagrams, the main features of typical standby system suitable for an industrial installation.

226.62 Explain the term 'Uninterruptable Power Supply' (UPS) and describe typical applications.

226.63 Describe, with the aid of diagrams, the main features of a UPS systems suitable for typical applications.
Applications: computer system, hospital installation

Test specification for written paper Electrical Plant and Equipment (8030-23-226)

This is a written examination paper lasting three hours and comprising ten questions. Candidates must answer **all** ten questions.

The examination paper will cover the knowledge specifications:

Topic	**Approximate % examination weighting**
General Machine Theory	15
Transformers	15
Synchronous machines	15
Induction machines	15
DC machines	15
Protection of machines	10
Special purpose machines and supplies	15

227 Advanced mathematics

Introduction

Much of the study of the technical units at the diploma and advanced diploma levels has integrated the mathematical content in with the applied technology. This unit, at the higher diploma level, provides additional mathematics to both advance and broaden a candidate's understanding of mathematics to supplement other studies at this level and to also provide a sound foundation for further study. Where possible, it is expected that worked examples will be selected to represent relevant engineering problems.

Knowledge requirements

Instructors must ensure that candidates are able to:

Trigonometry

227.1 Prove simple trigonometrical identities involving sin*A*, cos*A*, tan*A*, cosec*A*, sec*A* and cot*A*.

227.2 Use trigonometrical identities to assist in the solution of simple trigonometrical equations.

227.3 Manipulate and use the compound angle formulae expansions of $\sin(A+B)$, $\cos(A+B)$, $\tan(A+B)$ in the solution of trigonometric problems.

227.4 Manipulate and use the double angle formulae expansions of $\sin 2A$, $\cos 2A$ and $\tan 2A$ in the solution of trigonometric problems.

227.5 Manipulate and use the half angle formulae expansions of sin*A*, cos*A* and tan*A*, including those using the substitution $t = \tan \frac{A}{2}$ in the solution of trigonometric problems.

227.6 Transform expressions of the form $a \sin\theta \pm b\cos\theta$ to the form $r\sin(\theta + \alpha)$ and use this to solve problems.

Geometry

227.7 Create a diagram from given data to a suitable scale.

227.8 Estimate the area under curves between given limits by using the mid-ordinate, trapezoidal and Simpson rules.

227.9 State Pappus' theorems.

227.10 Use Pappus' theorems to calculate volumes and surface areas of curved shapes.

Algebra

227.11 Sketch graphs of the type $y–ae^{bx}$ and $a(1 – e^{bx})$ for given values of a and b.

227.12 Determine exponential / logarithmic laws by plotting graphs on log-log or log-linear graph paper for functions such as $y – ax^n$, $y–ae^{bx}$.

227.13 Determine the partial fractions for expression in which the denominator contains linear factors, repeated linear factors or quadratic factors ie functions of the following types

$$\frac{f(x)}{(x-a)(x-b)},\ \frac{f(x)}{(x-a)^3},\ \frac{f(x)}{ax^2+bx+c}$$

Complex Numbers

227.14 Define a complex quantity as a number which has real and imaginary parts.

227.15 Use the definition $j = \sqrt{-1}$ to identify the imaginary parts of a complex number.

227.16 Describe vectors and phasors as complex quantities.

227.17 Represent complex quantities on an Argand diagram using cartesian ($a \pm jb$) and polar ($r\angle\theta$) forms.

227.18 Identify $\pm j$ and $\pm\sqrt{J}$ as instructions to rotate phasors through angles of ±90° and ±45° respectively.

227.19 Convert complex quantities from cartesian form to polar form and vice versa.

227.20 Perform scalar multiplication and division on complex numbers in cartesian form.

227.21 Define and use the conjugate of a complex number.

227.22 Calculate the sums and differences of complex quantities.

227.23 Calculate the products and quotients of complex quantities.

227.24 Solve quadratic equations which produce complex roots.

Matrices and determinants

227.25 Calculate the sum and differences of TWO matrices (2x2 only).

227.26 Calculate the product of TWO 2x2 matrices.

227.27 Solve a pair of linear simultaneous equations using matrices.

227.28 Evaluate a 2x2 determinant.

227.29 Solve a pair of linear simultaneous equations using determinants.

Differential Calculus

227.30 Derive, from first principles, the differential coefficients for function such as $y = ax^n+b$.

227.31 Use the notations dy/dx, and d^2y/dx^2 or $f'(x)$ and $f''(x)$ for derived expressions noting that other variables, such as V, A, h and r, may be used for Volume, Area, height and radius.

227.32 Differentiate, by rule, a range of functions and combinations of functions noting that the constants may be positive, negative or fractional numbers.
Range of functions:

i	$y–ax^n \pm b^{xm} \pm a\sqrt{x^b}$	-where a,b,m, and n are constants
ii	$y + a \sin (b\theta + a)$	-similarly for other trigonometric functions
iii	$y = al_n (bx) –$	-similarly for functions involving $\log_{10}x$ and $_ex$
iv	$y = ab^x$	

227.33 Differentiate, by rule, functions of functions, products and quotients of functions for the range given in 227.32.

227.34 Obtain the first and second derivatives for the range of functions given in 227.32.

227.35 Determine turning points for the range of functions given in 227.32 and identify these as local maxima, local minima or points of inflection.

227.36 Solve problems involving maximum and minimum values.

227.37 Identify and use the first and second derivatives of a displacement / time function as velocity and acceleration respectively, for linear and angular motions.

Integral calculus

227.38 Determine the indefinite integrals of functions for the range given in 227.32 including integrals of the form $f'(x) / f(x)$, $f'(x)[f(x)]''$, integration by substitution and integration by parts.

227.39 Evaluate definite integrals of functions for the range given in 227.32 between various limits.

227.40 Solve problems involving definite integration by partial fractions of functions of the type given in 227.32.

227.41 Evaluate the area under a curve from the range in 227.32 as the integral between given limits.

227.42 Express and evaluate, by integration, the area between two curves from the range in 227.32.

227.43 Define and calculate the mean and root mean square values of the functions in 227.32 ii).

227.44 Calculate the centroid, first and second moments of area of plane figures.

Differential equations and Laplace transforms

227.45 Solve, by direct integration, equations of the form $\frac{dy}{dx} + bx + c = 0$.

227.46 Solve, by assuming a solution of the form $\theta\text{-}Ae^{bt}$, an equation of the form $\frac{d\theta}{dt} = k\theta$.

227.47 Solve differential equations arising from practical situations.

227.48 Define Laplace transformation and inverse transformation.

227.49 Use Laplace transforms and inverse transforms to solve first and second order differential equations for functions of t when $f(t) = k, t^n, e^{kt}$, $\sin \omega t$, $\cos \omega t$, $\sinh \omega t$, $\cosh \omega t$, and combinations of these.

Progressions and series

227.50 Define arithmetic progressions (AP's) and geometric progressions (GP's) as progressions having a common difference and common ratio between successive terms respectively.

227.51 Evaluate the sum of n terms of an arithmetic progression using the formula
$Sn = \frac{n[2a+d(n–1)]}{2}$ where a is the first term, d is the common difference and n is the number of terms.

227.52 Evaluate the sum of n terms in a geometric progression using the formula
$Sn = \frac{a(1–r^n)}{(1–r)}$, where a is the first term, d is the common ratio and n is the number of terms.

227.53 Deduce general expressions for the n^{th} term of simple arithmetic and geometric progressions.

227.54 Expand the general binomial expression $(a=b)^n$ for any positive integer value of n.

227.55 Write a single specified term from the expansion given in 227.54.

227.56 Use the binomial series to expand expressions such as $(1+x)^n$ for $–1<x<1$.

227.57 Use the binomial series to estimate the effects on the subject of a formula, involving power laws, when there are small percentage errors in the variables.

227.58 Describe the concept of convergence of a series to a limit.

227.59 Define the radius of convergence of a power series.

227.60 Use the ratio test to determine the radius of convergence of series expansions for functions such as e^x, $\sin x$, $\log_e (I+x)$ and $(I+X)^n$.

Complex waveforms

227.61 State that any periodic waveform can be regarded as the sum of the fundamental and harmonically related sinusoidal components.

227.62 Define the terms fundamental, second and third harmonic.

227.63 Show graphically the effects of adding second and third harmonics to a fundamental waveform.

227.64 Show graphically the effect of changing the amplitude and phase of the second harmonic component.

227.65 Derive an expression for a waveform comprising the fundamental and harmonic components of specified amplitudes.

227.66 Write an expression for a waveform comprising the fundamental with second and third harmonic components of specified amplitudes.

Probability

227.67 Define probability (p) and show that 0 ″ p ″ 1.

227.68 Define complementary probability (q) and show p + q = 1.

227.69 Calculate the values of probability in simple cases.

227.70 Define mutually exclusive events, independent events and dependent events.

227.71 Perform calculations related to simple cases of total and compound probability.

227.72 Define the classical probability P of an event A occurring as P(A)=n(A)/n(S), where n(A) is the number of ways A can occur and n(S) is the total number of ways that possible events can occur.

227.73 Solve simple problems using the multiplication law for probability of independent events.

227.74 Solve simple problems using the addition law for probability of independent events.

Test specification for written question paper Advanced Mathematics (8030-23-227)

This is a written examination paper lasting three hours with ten questions. Candidates must answer **all** ten questions.

The examination paper will cover the knowledge specifications:

Topic	Approximate % examination weighting
Trigonometry Geometry Algebra	20
Complex numbers	10
Matrices and determinants	10
Differential calculus Integral calculus Differential equations and Laplace transforms	30
Progressions and series	10
Complex waveforms	10
Probability	10

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Appendix A
Practical assignments

Two assessment methods are used in the 8030 (2000) Technician Awards in Electrical & Electronic Engineering programme – written questions and practical assignments.

Practical assignments
Some of the units or components in the advanced diploma level of this programme have a related practical assignment or assignments. These assignments may call on skills covered in other sections but reference is only made to the competences covered by the marking criteria. Wherever relevant the option is given for you to use local names, local currencies, alternative measurements and paper sizes, or to design an alternative assessment. **Where this option is taken the assignment must be of a comparable standard** to ensure consistency between centres using this programme. The assignment must be documented and available for the visiting verifier. ALL assignments must be successfully completed.

The assignments may be administered at any time convenient to the instructor and to the candidate.

The practical assignments in this publication are intended to be photocopied.

Instructor notes
It is essential that you read these before attempting to administer the practical assignment. Practical assignments usually require you to prepare material for the assignment.

Candidate instructions
Make sure every candidate has a copy of these before beginning the practical assignment.

Marking
The marking is based on performance criteria or outcomes related to the practical assignment, to which the answer will always be either 'yes – the candidate achieved this' or 'no – the candidate did not achieve this'. Credit is given for those performance competences for which the answer is 'yes – the candidate achieved this'.

Supervision
All assignments require supervision and you must make sure that the results reflect only the individual candidate's own work. You must keep all assessment documentation and material in a file for each candidate until the results have been agreed by the visiting verifier and until confirmation of results has been received from City & Guilds.

Records, results and certification
Successful completion of the related practical assignments for each unit needs to be recorded and then sent to City & Guilds. We suggest that you keep a record of each individual's achievements which may then be transferred to the entry forms. A model is given at the end of this section but you may use any form of record keeping that is convenient and accessible.

In order to gain certification, results for successfully completed practical assignments must be sent to City & Guilds. Results for practical assignments are entered onto Form S which is then countersigned by the visiting verifier and sent to us.

An advantage of this programme is that candidates who successfully complete the practical assignments for a single unit may, if they wish, claim a certificate of unit credit. This may be beneficial for those candidates who only wish to complete part of this programme. Send these claims to us at any time provided the visiting verifier has countersigned the Form S.

Candidates wishing to gain the full award (Certificate, Diploma or Advanced Diploma) must successfully complete all the relevant practical assignments. We recommend that their practical results are sent at the time of, or shortly before, the date of the written examinations.

Visiting verifier
The operation of this programme requires the appointment of a visiting verifier. The visiting verifier must countersign the results of the practical assignments on Form S. The visiting verifier should also be able to inspect records and candidates' work to verify the results before submission.

Advanced Technician Diploma in Applied Electrical Engineering
Candidate assessment record

***Candidates must complete these assignments**

Candidate's name and number

Centre name and number

Assessment reference	Date completed	Instructor signature	Instructor name
220/1 Engineering project*			

Advanced Technician Diploma in Applied Electrical Engineering
Candidate assessment record

***Candidates must complete these assignments**

Candidate's name and number

Centre name and number

Assessment reference	Date completed	Instructor signature	Instructor name
220/1 Engineering project*			

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