QUALIFICATION HANDBOOK

Level 2/3 Certificate/ Diploma in Telecommunication Systems (2730-12/13)

October 2017 Version 1.3

City & Guilds

Qualification at a glance

Subject area	Telecoms
City & Guilds number	2730
Age group approved	16+
Fast track	Available
Assessment	Short answer paper Assignment Online test
Support materials	Centre handbook Assessment pack Smartscreen
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	GLH	TQT	City & Guilds number	NQF Accreditation number
Level 2 Certificate in Telecommunication Systems	290	348	2730-12	601/1051/X
Level 3 Diploma in Telecommunication Systems	589	825	2730-13	601/0540/9

Version and date	Change detail	Section
1.1 August 2013	NQF Accreditation numbers added	Page 2
1.2 October 2013	Formatting of unit 304 to display numbering and range correctly	Unit 304
1.3 October 2017	Added TQT details Deleted QCF	**Qualification at a glance & Structure** **Throughout**

Contents

1 Introduction

This document tells you what you need to do to deliver the qualifications:

Area	Description
Who are the qualifications for?	The qualification(s) have been designed for learners seeking careers in the telecommunication industry.
What do the qualifications cover?	The qualifications allow learners to develop and practise the skills required for working with electrical, digital and radio telecommunication systems. It will also cover the basic mathematical knowledge needed to support learners in obtaining technical competency across the various telecommunication system modules.
What opportunities for progression are there?	Learners that complete 2730-12 (level 2) should be able to obtain employment within the telecommunications industry at the technician level in the fields of installation, maintenance or transmission and operation. On completing 2730-13 (level 3) learners should have a well developed knowledge of the technical and design principles of complex telecommunication systems enabling them to fulfil the role of technician/senior technician across a range of specialised disciplines. Besides progression opportunities from 2730-12 (level 2) to 2730-13 (level 3) and 2730-03 (level 5), other progression opportunities include: • ILM Leadership Management qualifications • 9200 Professional Recognition Awards
This qualification replaces	2730-01 Technician Certificate in Telecommunication Systems 2730-02 Technician Diploma in Telecommunication Systems 2730 Registration expiry: 31 March 2014 2730 Certification expiry: 31 May 2015

Qualification structure

This section provides information about the structure of the qualification and the unit combinations required.

Level 2 Certificate in Telecommunication Systems (2730-12)

To achieve the Level 2 Certificate in Telecommunication Systems, learners must achieve units 205 - 207 plus:

- One unit from **either** unit 203 **or** 253
- And one unit from **either** unit 204 **or** 254

Level 2 Certificate in Telecommunication Systems	
Full Rules of combination	Unit 205 – 207 **plus** one unit from 203 or 253 **and** one unit from 204 or 254

Learners can achieve unit 208 as an elective unit – credit achieved from this unit will not count towards the overall qualification.

Level 3 Diploma in Telecommunications Systems (2730-13)

To achieve the Level 3 Diploma in Telecommunications Systems learners must achieve units

301 – 305, 307, 352 and 354
Or
301 – 304, 306 – 307, 352, 354 and 356

Level 3 Diploma in Telecommunications Systems	
Full Rules of combination	Units 301 – 305, 307, 352 and 354 **Or** Units 301 – 304, 306 – 307, 352, 354 and 356

Learners can achieve unit 308 as an elective unit – credit achieved from this unit will not count towards the overall qualification.

Total Qualification Time

Total Qualification Time (TQT) is the total amount of time, in hours, expected to be spent by a Learner to achieve a qualification. It includes both guided learning hours (which are listed separately) and hours spent in preparation, study and assessment.

Title and level	**GLH**	**TQT**
Level 2 Certificate in Telecommunication Systems	290	348
Level 3 Diploma in Telecommunication Systems	589	825

Full qualifications

The qualifications will be awarded to learners on successful completion of the required units as shown in the tables above.

A certificate will be issued to learners for each successfully completed qualification. Each qualification is made up of a cluster of units as illustrated above.

Guided Learning Hours

City & Guilds defines Guided Learning Hours (GLH) as the amount of contact time, including assessment, which is likely to be required for a Learner to complete all the knowledge and practical requirements for the qualification for which he or she is studying. Additional time may be required by learners for self study, research and unsupervised practice and by Tutors for day-to-day marking of assignments or homework where the Learner is not present.

The recommended GLH for learners to complete any of the four pathways available is 270 hours per pathway. The below table provides the GHL per unit.

City & Guilds unit no.	Level	Unit title	Assessed by
203	2	Fundamentals of electronic communication 1	Multiple choice dated entry
204	2	Communication Systems and Digital Networks 1	Multiple choice dated entry
205	2	Mathematics	Short answer question paper
206	2	Fundamentals of electronic communication 1 - Practical	Practical Assignment
207	2	Communication Systems and Digital Networks 1 - Practical	Practical Assignment
253	2	Fundamentals of electronic communication 1 - Online	On-line test
254	2	Communication Systems and Digital Networks 1 - Online	On-line test
301	3	Fundamentals of Electronic Communication 2	Short answer question paper
302	3	Communication Systems and Digital Networks 2	Short answer question paper
303	3	Fundamentals of Electronic Communication 3	Short answer question paper
304	3	Communication Systems and Digital Networks 3	Short answer question paper
305	3	Radio Systems	Short answer question paper
306	3	Programming principles	Short answer question paper
307	3	Advanced Mathematics	Short answer question paper
352	3	Communication Systems and Digital Networks 2 – Practical	Practical Assignment
354	3	Communication Systems and Digital Networks 3 – Practical	Practical Assignment
356	3	Programming principles – Practical	Practical Assignment

Elective units

City & Guilds unit no.	Level	Unit title	Assessed by
208	2	Constructing, testing and fault finding electronic circuits	Practical Assignment
308	3	Maintenance of electrical equipment and systems	Practical Assignment

City & Guilds qualification levels

NQF… Levels	City & Guilds qualifications (examples)	Regional qualifications*	UK and general qualifications (approximate equivalent)
8	City & Guilds Fellowship (FCGI)		Doctoral
7	City & Guilds Membership (MCGI) ILM Fellowship (FInstILM) Master Professional Diploma ILM Diploma in Strategic Leadership and Executive Management		Master's Degree Postgraduate Diploma and Certificate
6	City & Guilds Graduateship (GCGI) ILM Membership (MInstILM)	Broadly equivalent to each of the three years of undergraduate education	Bachelor's Degree
5	Level 5 Vocational Awards IVQ Advanced Technician Diploma Full Technological Diploma ILM Level 5 Diploma in Management		Higher National Diploma Foundation Degree Diplomas of Higher and Further Education
4	Level 4 Vocational Qualification Higher Professional Diploma City & Guilds Licentiateship (LCGI) ILM Level 4 Certificate in Management		Certificate of Higher Education Higher National Certificate
3	IVQ Technician Diploma IVQ Advanced Diploma Level 3 Vocational Awards ILM Level 3 Award in First Line Management Advanced Apprenticeship	Advanced Proficiency*	A Level
2	IVQ Technician Certificate IVQ Diploma Level 2 Vocational Awards	NVQ/CVQ Level 2* CSEC I – III*	GCSE A - C
1	IVQ Certificate Introductory Awards Level 1 Vocational Awards	NVQ/CVQ Level 1* CSEC IV – VI*	GCSE D – G

… National Qualifications Framework and Qualifications and Credit Framework in England
** Nearest Comparable Level*

2 Centre requirements

Approval

This section outlines the approval processes for centres to offer these qualifications and any resources that Centres will need in place to offer the qualifications including qualification-specific requirements for centre staff.

Only approved organisations can offer City & Guilds qualifications. Organisations approved by City & Guilds are referred to as centres.

Centres must meet a set of quality criteria including:

- provision of adequate resources, both physical and human
- clear management information systems
- effective assessment and quality assurance procedures
- effective Learner support
- reliable recording systems.

Centre staff should familiarise themselves with the structure, content and assessment requirements of the qualification[s] before designing a course programme.

An organisation that has not previously offered City & Guilds qualifications must apply for approval to become a centre. This is known as the **Centre Approval Process** (**CAP**). Centres also need approval to offer a specific qualification. This is known as the **Qualification Approval Process** (**QAP**).. In order to offer this qualification, organisations which are not already City & Guilds centres must apply for centre and qualification approval at the same time. Existing City & Guilds centres not already delivering the existing 2730 Telecommunication qualifications will only need to apply for qualification approval for these particular qualifications. Full details of the procedures and forms for applying for centre and qualification approval are given in the *Centre Manual - Supporting Customer Excellence* (UK customers only) and the *CentreGuide/ Manual-Delivering International Qualifications (International customers).*

If your Centre is already approved to offer the following qualification:

- 2730-01 Technician Certificate in Telecommunication Systems
- 2730-02 Technician Diploma in Telecommunication Systems

you can apply for approval for the new:

- 2730-12 Level 2 Technician Certificate in Telecommunication Systems
- 2730-13 Level 3 Technician Diploma in Telecommunications Systems

using the **Fast Track Approval Form**, available from the City & Guilds website or your local City & Guilds office

Centres should use the Fast Track Form if:

- there have been no changes to the way the qualifications are delivered, and
- they meet all of the approval criteria in the fast track form guidance notes.

Fast track approval is available for 12 months from the launch of the qualification. After 12 months, the Centre will have to go through the standard Qualification Approval Process. The centre is responsible for checking that fast track approval is still current at the time of application.

Qualification approval confirmation allows approved centres to register learners only. Approval to certificate learners for practical units is only granted by your local office after positive monitoring/verification visit by your City & Guilds' appointed Qualification Consultant/External Verifier.

Assessment must not be undertaken until qualification approval has been obtained.

City & Guilds reserves the right to suspend an approved centre, or withdraw its qualification approval for reasons of debt, malpractice or non compliance with City & Guilds' policies, regulations, requirements, procedures and guidelines, or for any reason that maybe detrimental to the maintenance of authentic, reliable and valid qualifications or that may prejudice the name of City & Guilds.

Resource requirements

Centre staffing

To meet the quality assurance criteria for this qualification, the centre must ensure that the following internal roles are undertaken:

- Assessment Manager
- Tutor/Assessor
- Internal Verifier Co-ordinator (for larger centres)
- Internal Verifier/Internal Quality Assurer
- Examinations Secretary
- Invigilator

Staff delivering these qualifications must satisfy the requirements for occupational expertise for these qualifications.

Assessor and Internal Verifier/Quality Assurer must:

- be occupationally competent or technically knowledgeable in the areas for which they are delivering training and/or have experience of providing training. This knowledge must be at least to the same level as the training being delivered

- have credible experience of providing training.
- have verifiable, recent and relevant industry experience and competence of the occupational working area at or above the level being assessed and evidence of the quality of occupational experience to ensure the credibility of the assessment judgements. Appropriate evidence will include:
    - curriculum vitae and references
    - achievement of relevant qualifications
    - continuing professional development (CPD) records
    - current employment
    - product/video evidence

  This list is not exhaustive and other relevant methods may be considered. Please contact your City & Guilds local office for guidance.
- must be competent and experienced in making accurate assessment decisions; it is therefore highly recommended that an appropriate assessor and internal verifier/quality assurance qualification have been obtained or that they are being worked towards.
- only assess or quality assure in their acknowledged area of occupational competence.
- participate in relevant training activities for their continued professional development (see CPD requirements).
- be able to read, write, listen and speak English, to the equivalent level of IESOL (common B1/B2).

Newly qualified Telecommunication Technicians must have gained significant post qualification commercial experience before commencing these roles. For the avoidance of doubt, those who have no occupational

Centre staff may undertake more than one role, eg tutor and assessor or internal quality assurer, but cannot internally verify their own assessments.

Assessors and Internal Quality Assurer

The Training, Assessment & Quality Assurance (TAQA) qualifications for Assessor and Internal Verifier/Quality Assurer are valued as qualifications for centre staff, but they are not currently a requirement. However a national TAQA qualification equivalent is required to be able to show occupational competence, through mapping their competences and knowledge against the relevant National Occupational Standard and the assessor and internal verifier/quality assurer requirements.

Alternatively City & Guilds recommends that staff delivering the 2730Telecommunictaion Systems qualifications should hold or be working towards the unit from the IVQ in Teaching, Training and Assessing Learning qualification (1106 or equivalent) which level is relevant to their role.

Continuing professional development (CPD) records

Centres must support their staff to ensure that they have current knowledge of the occupational area, that delivery, mentoring, training, assessment and verification is in line with best practice, and that it takes account of any national or legislative developments.

Centres are also required to continuously monitor and keep records of their staff CPD activities to ensure staff keep their technical skills and

knowledge up-to-date and to the relevant occupational level for which they are assessing/quality assuring.

Assessors and internal verifiers/quality assurers should select CPD methods that are appropriate to meeting their development needs. The CPD requirement must be carried out on **one or a combination of** the types of activities listed below. **No activity will carry a 'double hours' allowance.**

The following provides an example of a variety of methods that can be used for CPD purposes.

Updating occupational competence and expertise

- internal and external work placements
- work experience and shadowing (e.g. within associated departments)
- external visits to other organisations
- updated and new training and qualifications
- technical training that develops new and/or updates existing skills
- visits to educational establishments
- trade fairs
- 'hands on' practice of telecommunication skills in a commercial environment (current job) that can be shown to develop individual skill and knowledge levels

Updating occupational knowledge/keeping up to date with sector developments and new legislation

- relevant sector websites
- membership of professional bodies
- papers and documents on legislative change
- networking events
- seminars, conferences, workshops, membership of committees / working parties
- staff development days
- technical training that develops new and/or updates existing knowledge levels
- further relevant qualifications.

Standardising and best practice in assessment

- Regular standardisation meetings with colleagues
- Sharing best practice through internal meetings, news letters, email circulars
- Comparison of assessment and verification in other sectors
- Attending awarding body meetings / seminars /workshops

The following activities **would not** count towards CPD:

- reading the trade press and books
- listening to tapes and watching DVDs .

Individuals must provide relevant and suitable evidence that CPD has taken place within each 12 month period to be measured from 1 September - 31 August.

Physical resource requirement

Equipment

Centres wishing to deliver this qualification must review this handbook and ensure that they have access to sufficient range of services, professional products, tools, materials and equipment in the centre or workplace so that Learners have the opportunity to cover all of the practical activities of the qualification.

The setting should take account of any bye-laws, legislation or legal authority requirements that would affect commercial establishments.

It is acceptable for a centre to use specifically designated areas within a centre if the Learner does not have a work placement. Where facilities do not exist for realistic practical work, it is strongly recommended that centres develop links with local organisations to provide opportunities for hands on experience.

Examination rooms

A suitable, controlled area for testing must be provided and arrangements musts be made for the secure storage of assessment materials and records.

Acceptable facilities for e-volve online testing must be maintained where the online testing of knowledge and understanding is required.

UK customers should refer to the *current JCQ Instructions for conducting examinations and* International customers should

refer to the latest *Regulations for the conduct of examinations* for full details.

Realistic Learning environment

City & Guilds vocational related qualification must be assessed in facilities that meet acceptable, current industry standards for the specific qualification area.

Centres must ensure that access to the range of equipment is maintained in the centre and / or workplace to meet the qualification needs and enable learners' to cover all of the required practical activities.

The learning and assessment setting may incorporate a real, or simulated but realistic learning environment. These facilities must provide learners with experience of working in and under realistic commercial conditions during assessment:

- time pressures
- work problems
- interruptions
- accountibilities
- office environement
- tools to do the job

The learning environment must meet any bye-laws, legislation or legal authority requirements that would affect a similar commercial establishment as well as meeting the requirements of a vocational education establishment.

Other legal considerations

Other legal considerations may apply to this qualification. It is the responsibility of the training provider to ensure compliance with all local, regional and national legislation which may affect delivery of the qualification, and to ensure that Learners are fully aware of any requirements.

Learner entry requirements

City & Guilds does not set entry requirements for these qualifications. However, centres must ensure that learners have the potential and opportunity to gain the qualifications successfully.

Learners must have an adequate level of English speaking, reading, listening and writing skills to competently cover aspects of this qualification such as answering underpinning knowledge questions orally and/or in writing, and reading assessor notes regarding their observations.

Age restrictions

These Levels 2 and 3 qualifications at Levels 2 and 3 have been identified as **not suitable for learners under the age of 16**.

Centres and learners should be fully aware of minimum age requirements and any implications on completing assessments.

All qualifications are suitable for 16+ learners; therefore City & Guilds cannot accept any registrations for learners under 16 as these qualifications are not approved for under 16s.

3 Delivering the qualification

Initial assessment and induction

An initial assessment of each Learner should be made before the start of their programme to identify:

- if the Learner has any specific training needs,
- support and guidance they may need when working towards their qualifications.
- any units they have already completed, or credit they have accumulated which is relevant to the qualifications.
- the appropriate type and level of qualification the Learner should be entered for

We recommend that centres provide an induction programme so the Learner fully understands the requirements of the qualifications they will work towards, their responsibilities as a Learner, and the responsibilities of the centre. It may be helpful to record this information on a learning contract or Individual Learning Plan.

Further guidance about initial assessment and induction, as well as learning contract that centre may use, are available on the City & Guilds website.

Recommended delivery strategies

Centre staff should familiarise themselves with the structure, content and assessment requirements of the qualifications before designing a course programme. More information on practical units and assessment requirements can be found in the Assessment Guide available from the Walled Garden. In particular, staff should consider the skills and knowledge related to the local National Occupational Standards.

Provided that the requirements for the qualification are met, centres may design course programmes of study in any way that they feel best meets the needs and capabilities of their Learners. Centres may wish to include topics as part of the course programme, which will not be assessed through the qualifications.

Learner Registration and certification

Learners must be registered with City & Guilds at the earliest opportunity and **within 12 weeks** of commencing the programme at the Centre.

This enables the Qualification Consultant/External Verifier to plan effective verification strategies based on accurate details of the number of Learners at a centre. Registration details of all Learners must be made

available to the Qualification Consultant/External Verifier at the first monitoring/verification visit after centre approval is confirmed.

Registration and certification details provided by City & Guilds will alert Qualification Consultant/External Verifiers to instances of Learners being both registered and certificated between centre visits. This process ensures that these Learners are considered for inclusion in the sampling plan for the next centre visit.

City & Guilds require that centres maintain at least **ten weeks between Learner registration and certification** and will reject any certificate claims for Learners not registered accordingly.

Please note that the effective date for registration is the date Learner details are processed through the computer system at City & Guilds.

Full details of City & Guilds' administrative procedures for these qualifications are provided online to City & Guilds registered centres via the **Walled Garden**. This information includes details on Learner registration requirement, enrolment numbers, fees, entry for examinations and certification. Centres should follow all guidance carefully, particularly noting that fees, registration and certification end dates for the qualifications are subject to change.

After completion of each theory unit, all Learners will receive, via their centre, a **Notification of Learner results**, giving details of how they performed. It is not a certificate of achievement.

The Notification of Learner results and certificates will be issued by City & Guilds to the centre for award to successful Learners. Any enquiries about results and certification must be conducted through the Learner's centre.

Centres will also receive a consolidated results list detailing the performance of all Learners they enter, whether they are successful or not.

Further information about the issue of results and certification for centres is available online at **www.cityandguilds.com** or by contacting the nearest City & Guilds office.

Assessment language

We realise that learners may ask to take assessment in their own language. Where assessments are carried out in a language other than English, City & Guilds approved centres must provide evidence that Centre staff and learners are must have an adequate level of English speaking, reading, listening and writing skills to competently cover aspects of this qualification such as answering underpinning knowledge questions orally and/or in writing, and reading assessor notes regarding their observations.

Access to assessment

There are no formal entry requirements for Learners undertaking this qualification. However centres must ensure that Learners have the potential and opportunity to successfully gain the qualification.

Aids or appliances which are designed to alleviate disability may be used during assessment providing they do not compromise the standard required.

City & Guilds provides guidance and regulations to facilitate fair access to assessments and qualifications for learners who are eligible for adjustments to assessment arrangements. Access arrangements are designed to allow attainment to be demonstrated. For further information, please see *Access to assessment and qualifications*, available on the City & Guilds website.

Equal opportunities

It is a requirement of centre approval that centres have an equal opportunities policy. The regulatory authorities require City & Guilds to monitor centres to ensure that equal opportunity policies are being followed.

City & Guilds' own equal opportunities policy is available to download from the City & Guilds website.

Further information on equal opportunities is given in the *Centre Manual - Supporting Customer Excellence* (UK customers only) and the *CentreGuide/ Manual-Delivering International Qualifications (International customers).*

Health and safety

The requirement to follow safe working practices is an integral part of all City & Guilds qualifications and assessments, and it is the responsibility of centres to ensure that all relevant health and safety requirements are in place before learners start practical assessments and meet local national requirements.

Should a Learner fail to follow health and safety practice and procedures during an assessment (for example, practical assessment, assignment) the assessment must be stopped and the Learner advised of the reasons why. The Learner should be informed that they have failed the assessment. Learners may retake the assessment at a later date, at the discretion of the centre. In any cases of doubt, guidance should be sought from your local City & Guilds office and/or Qualification Consultant/External Verifier.

Data protection and confidentiality

Centres offering these qualifications may need to provide City & Guilds with personal data for staff and learners.

Data protection and confidentiality must not be overlooked when planning the delivery of this qualification. Guidance on data protection and the obligations of City & Guilds and centres are explained in the

Centre Manual - Supporting Customer Excellence (UK customers only) and the *CentreGuide/ Manual-Delivering International Qualifications (International customers).*

Retention of assessment records and learner evidence

In order to comply with regulatory requirement (Ofqual) and to fully support learners, centres are required to retain learners' evidence until the Learner has certificated and until any final external verification sampling has taken place. Learner assessment **records** (see the *Centre Manual - Supporting Customer Excellence* (UK customers only) and the *Centre Guide/ Manual-Delivering International Qualifications (International customers)* must be retained for **three years** after certification. Records must also be kept in accordance with local national Data Protection regulations.

Appeals

Centres must have their own, auditable, appeals procedure that must be explained to learners during their induction. Appeals must be fully documented by the Quality Assurance Co-ordinator and made available to the Qualification Consultant/External Verifier or City & Guilds.

Further information on appeals is given in the *Centre Manual - Supporting Customer Excellence* (UK customers only) and the *Centre Guide/ Manual-Delivering International Qualifications (International customers).*
. There is also appeals information for centres and learners on the City & Guilds website.

Support materials

The following resources are available for these qualifications:

Description	How to access
Qualification handbook	www.cityandguilds.com
Assessment pack	www.cityandguilds.com
fast track approval forms/generic fast track approval form	www.cityandguilds.com
SmartScreen	www.smartscreen.co.uk
Recording forms	www.cityandguilds.com

Recording documents

City & Guilds has developed a set of *Recording forms* including examples of completed forms, for new and existing centres to use as appropriate. Recording forms are available on the City & Guilds website.

Although new centres are expected to use these forms, centres may devise or customise alternative forms, which must be approved for use by the qualification consultant/external verifier, before they are used by learners and assessors at the centre. Amendable Word versions of the forms are also available on the City & Guilds website.

Learner portfolio of evidence

Evidence should be presented in a portfolio, signed and dated by the Learner and assessor using the appropriate recording forms. City & Guilds has developed a set of *Recording forms* including examples of completed forms, for new and existing centres to use as appropriate. Recording forms are available on the City & Guilds website.

Learners and centres may decide to use a paper-based or electronic method of recording evidence.

City & Guilds endorses several e-Portfolio systems, including our own, Learning Assistant, an easy-to-use and secure online tool to support and evidence learners' progress towards achieving qualifications. Further details are available at wwwcityandguilds.com/e-portfolios.

Dated examinations and e-assessment platform

Dated examinations available on specific dates each year are also available on-demand when using our flexible online assessment platform e-volve.

Getting set up on e-volve

Our online e-assesment platform is easy to set up and use. More information about e-volve, including technical documentation, user guides, Q&As, webinars and step by step tutorials visit **e-volve familiarisation** pages on our website. To apply and gain access to the e-platform completes the on-line application from our website.

Quality Assurance

Internal quality assurance

Centres are responsible for internal quality assurance, and City & Guilds is responsible for external quality assurance. As such approved centres must have effective quality assurance systems to ensure optimum delivery and assessment of qualifications.

Quality assurance includes initial centre approval, qualification approval and the centre's own internal procedures for monitoring quality.

To meet the quality assurance criteria for this qualification, the centre must ensure that the following internal roles are undertaken:

- Assessment Manager
- Tutor/Assessor
- Internal Verifier Co-ordinator (for larger centres)
- Internal Verifier/Internal Quality Assurer
- Examinations Secretary
- Invigilator

The following is a summary of the key roles involved in the successful implementation and assessment of the qualification. Full details of the roles are given in the *Centre Manual - Supporting Customer Excellence* (UK customers only) and the *Centre Guide/ Manual-Delivering International Qualifications (International customers).*

The role of the **Internal Verifier/Quality Assurer** is to ensure that:

- they liaise with City & Guilds personnel
- there are adequate resources, both staff and materials
- the work of all personnel contributing to the delivery and assessment of the programme is sampled by a range of methods which should include sampling the observation checklist, Learner training plans and multiple choice quiz responses
- records of all sampling activities are monitored and maintained
- where several members of staff are involved in the delivery/assessment of the qualification, that there is a consistent interpretation of the requirements through standardisation activities and that these are documented
- all staff carrying out delivery and assessment are familiar with and understand the qualification requirements
- an appropriate referral policy is in place
- an appropriate appeals procedure is in place
- Learner evidence is clearly organised and accessible to the Internal and External verifier
- relevant records and pro formas are completed, maintained and retained for the purposes of Internal and External Verification along with the record of course delivery form.

The role of the **Tutor/Assessor** is to:

- plan, manage, deliver and assess the qualification using the City and Guilds materials provided
- ensure availability of technical support for ICT equipment
- ensure that each Learner is aware of the assessment requirements throughout their programme of learning
- provide guidance and support to Learners on the assessment and evidence requirements for the qualification
- ensure that the assessment and evidence requirements have been met by the Learner
- observe Learners' delivered sessions
- facilitate the multiple choice quiz and mark Learner responses
- complete relevant records and pro formas.

Full details and guidance on the internal and external quality assurance requirements and procedures are provided in *Centre Manual – Supporting Customer Excellence (UK customers) and Centre Guide/Manual – Delivering International Qualifications (International customers)*. These documents also explain the tasks, activities and responsibilities of quality assurance staff.

Expert witness

Where observation of process is used to obtain the performance evidence, this observation must be carried out against the standards. Best practice would require that such observation is carried out by a qualified Assessor. If this is not practicable then alternative sources of evidence may be used.

This could be a supervisor, mentor or manager, who may be regarded as a suitable witness to the Learner's capability. However, the witness must be technically capable in the process or skills that they are providing testimony for to at least the same level of expertise as that required of the

Learner and also understand the requirements of the standards. It is the responsibility of the Assessor to ensure sure that any witness testimonies accepted as evidence of a Learner's capability are valid to the standards by which the Learner is being assessed.

External quality assurance

External quality assurance for the qualifications will be provided by the usual City & Guilds external verification/centre monitoring process and reported on using relevant documentation.

Qualification consultants/ External verifiers are appointed by City & Guilds to approve centres, and to monitor the assessment and internal quality assurance carried out by centres. Monitoring activities/external verification visits are carried out to ensure that there is validity, reliability and good practice in centres.

To carry out their quality assurance role Qualification consultants/ /External verifiers must have appropriate occupational and verifying knowledge and expertise. City & Guilds Qualification Consultant/External Verifiers attend training and development designed to keep them up-to-date, to facilitate standardisation between Qualification consultants/ /External verifiers and to share good practice.

4 Assessment

Learners must:

- successfully complete the required online test/assignment for each mandatory unit
- successfully complete the required online test/assignment for each optional unit

City & Guilds has written the following assessments to use with this qualification:

- online multiple choice tests, using e-volve
- practical assignments
- Short answer question papers

Performance evidence requirements

Usually evidence of Learner performance will be derived from Assessor observation and/or testimony from an expert witness of the Learner carrying out work activities in the workplace.

Practical evidence must be the main form of evidence gathered. In order to demonstrate consistent, capable performance for a unit, a minimum of two separate practical observations will be required to show that the tasks reflected by the unit have been carried out to the stated standards. The knowledge and outcomes specified for each unit must be covered (e.g. four from a choice of six). It is possible that some of the outcomes in each unit are covered more than once. If, however, the two examples of practical evidence are not sufficient to cover all the specified outcomes, then further examples of practical evidence will be required to ensure that coverage is achieved.

Assessors must make sure that the evidence provided reflects the Learner's capability and not just the achievement of the training programme.

In cases of emergency, a breach of confidentiality/privacy or a dangerous working environment the following evidence can be used with agreement from the Qualification Consultant/External Verifier:

- products of the Learner's work, such as items that have been produced or worked on, documents produced as part of a work activity, records or photographs of the product.

If there is any doubt as to what constitutes suitable evidence, the Qualification Consultant/External Verifier should be consulted.

Knowledge evidence

In addition to the knowledge requirements being positively inferred from an Assessor or expert witness observing the practical tasks the Learner must be formally questioned on knowledge and understanding, using either short written answer or oral types of questions. The questions and answers must be recorded and should only relate to the specific areas defined by the outcomes for the unit.

The *Underpinning knowledge* form taken from the *Recording forms* document which City & Guilds has developed, for new and existing centres could be used. *Recording forms* are available on the City & Guilds website.

Assessors must carefully plan all types of questioning procedures beforehand. The actual questions (oral and written) must be kept under secure conditions and only made available to the Learners during the assessment process. Assessors should ask enough questions to be able to determine that the Learner has an appropriate level of knowledge and understanding as required by the unit.

The Learners will retain a copy of their results, including comments made by the Assessor during oral questioning. Assessors must make the questions available to Internal Verifiers/Internal Quality Assurer so that the latter can compare them against the results sheets held by the Learners.

The knowledge evidence should be referenced in a similar fashion to that used for practical evidence.

Oral questions need to be recorded with their answers within the Learner's file/portfolio of evidence. An Evidence location sheet taken from the *Recording forms* document which City & Guilds has developed must be completed to identify which unit evidence is referenced to, and to ensure quality for verification purposes.

City & Guilds unit no.	Level	Unit title	Assessed by	Where to obtain assessment materials
203	2	Fundamentals of electronic communication 1	Multiple choice dated entry	Walled Garden
204	2	Communication Systems and Digital Networks 1	Multiple choice dated entry	Walled Garden
205	2	Mathematics	Short answer question paper	Walled Garden
206	2	Fundamentals of electronic communication 1 – Practical	Practical Assignment	www.cityandguilds.com
207	2	Communication Systems and Digital Networks 1 – Practical	Practical Assignment	www.cityandguilds.com
253	2	Fundamentals of electronic communication 1	On-line test	N/A Examinations provided on e-volve.
254	2	Communication Systems and Digital Networks 1	On-line test	N/A Examinations provided on e-volve.
301	3	Fundamentals of Electronic Communication 2	Short answer question paper	Walled Garden
302	3	Communication Systems and Digital Networks 2	Short answer question paper	Walled Garden
303	3	Fundamentals of Electronic Communication 3	Short answer question paper	Walled Garden
304	3	Communication Systems and Digital Networks 3	Short answer question paper	Walled Garden
305	3	Radio Systems	Short answer question paper	Walled Garden
306	3	Programming	Short	Walled Garden

		principles	answer question paper	
307	3	Advanced Mathematics	Short answer question paper	Walled Garden
352	3	Communication Systems and Digital Networks 2 – Practical	Practical Assignment	www.cityandguilds.com
354	3	Communication Systems and Digital Networks 3 – Practical	Practical Assignment	www.cityandguilds.com
356	3	Programming principles – Practical	Practical Assignment	www.cityandguilds.com

Elective units

City & Guilds unit no.	Level	Unit title	Assessed by	Where to obtain assessment materials
208	2	Constructing, testing and fault finding electronic circuits	Practical Assignment	www.cityandguilds.com
308	3	Maintenance of electrical equipment and systems	Practical Assignment	www.cityandguilds.com

Time constraints

The following must be applied to the assessment of this qualification:

- Learners must finish their assessment within their period of registration
- Assignments should take no longer than 8 hours (Level 2), 9 hours (Level 3). If they do, centres should consider why this is, and make sure that they are not trying to gather too much evidence.

Test specifications

The way the knowledge is covered by each test is laid out in the table[s] below:

Test 1: Unit 203/253 Fundamentals of electronic communication 1
Duration: 2 hours (60 questions)

Unit	Outcome	%
203	1 health and safety in the workplace	10
	2 introduction to the use of computer technology	12
	3 science and electronics	78
	Total	**100**

Test 2: Unit 204/254 Communication systems and digital networks
Duration: 2 hours (60 questions)

Unit	Outcome	%
204	1 information transmission	13
	2 Basic telecommunication systems	15
	3 Optical fibre systems	9
	4 Principles of radio	13
	5 Mobile radio and cellular telephone systems	13
	6 Television	5
	7 Public Switched Telephone Networks (PSTNs)	13
	8 Digital networks and data communication	19
	Total	**100**

Test 3: Unit 205 Mathematics
Duration: 3 hours (9 questions)

Unit	Outcome	%
205	1 Electronic calculators and SI units	10
	2 Algebra	15
	3 Laws of indicies	10
	4 Geometry	10
	5 Trigonometry	15
	6 Graphs	10
	7 Number systems	10
	8 Basic statistics	10
	9 Logarithms and indicial equations	10
	Total	**100**

Test 4: Unit 301 Fundamentals of electronic communication 2
Duration: 3 hours (10 questions)

Unit	Outcome	%
301	1 boolean algebra, combinational logic gates and relaxation oscillators	20
	2 terminology and requirements of simple telecommunication networks	18
	3 the nature, sources and effects of noise on telecommunications and the use of decibels as the unit of measurement	14
	4 characteristics of transmission lines and cables used for telecommunication	14
	5 effects of capacitors and inductors in filters and oscillators	16
	6 principles of communicating information by varying the characteristics of high frequency waveform	18
	Total	**100**

Test 5: Unit 302 Communication systems and digital networks 2
Duration: 3 hours (10 questions)

Unit	Outcome	%
302	1 data communication fundamentals	10
	2 the open systems interconnection (OSI) reference model	10
	3 transmission control protocol / internet protocol (TCP/IP)	25
	4 data packets, frames and cells	25
	5 switching and routing	30
	Total	**100**

Test 6: Unit 303 Fundamentals of electronic communication 3
Duration: 3 hours (10 questions)

Unit	Outcome	%
303	1 power supply systems	10
	2 optical fibre systems	12
	3 modulation and modems	16
	4 digital transmission and multiplexing	16
	5 pulse modulation and time division multiplexing (TDM)	22
	6 access network and digital telephone exchanges	24
	Total	**100**

Test 7: Unit 304 Communication systems and digital networks 3
Duration: 3 hours (10 questions)

Unit	Outcome	%
304	1 structured cabling	16
	2 local area networks (LANs), metropolitan area networks (mans) and wide area networks (wans)	20
	3 transmission systems	12
	4 end systems	16
	5 network management	20
	6 internet data center (IDC)	16
	Total	**100**

Test 8: Unit 305 Radio systems
Duration: 3 hours (10 questions)

Unit	Outcome	%
305	1 fundamentals of electromagnetic radiation	5
	2 antennas and feeder systems	12
	3 terrestrial radio propagation	10
	4 radio transmitters	20
	5 radio receivers	25
	6 mobile telecommunications systems	20
	7 satellites	8
	Total	**100**

Test 9: Unit 306 Programming principles
Duration: 3 hours (10 questions)

Unit	Outcome	%
306	1 fundamentals of programming	40
	2 basic programming concepts	60
	Total	**100**

Test 10: Unit 307 Advanced mathematics
Duration: 2 hours (7 questions)

Unit	Outcome	%
307	1 linear equations and transposition	10
	2 quadratic functions	10
	3 linear law fitting	15
	4 graphs	15
	5 complex numbers	15
	6 trigonometry	20
	7 calculus	15
	Total	**100**

Recognition of prior learning (RPL)

Recognition of prior learning means using a person's previous experience or qualifications which have already been achieved to contribute to a new qualification. RPL is not allowed for this qualification.

5 Units

Availability of units

Below is a list of the learning outcomes for all the units.

Structure of units

These units each have the following:

- City & Guilds reference number
- title
- level
- guided learning hours
- unit aim
- learning outcomes which are comprised of a number of assessment criteria
- notes for guidance.

Summary of units

City & Guilds unit no.	Level	Unit title
203	2	Fundamentals of electronic communication 1
204	2	Communication Systems and Digital Networks 1
205	2	Mathematics
301	3	Fundamentals of Electronic Communication 2
302	3	Communication Systems and Digital Networks 2
303	3	Fundamentals of Electronic Communication 3
304	3	Communication Systems and Digital Networks 3
305	3	Radio Systems
306	3	Programming principles
307	3	Advanced Mathematics

Unit 203 Fundamentals of electronic communication 1

Level:	2
GLH:	100
Aim:	This unit covers health and safety in the workplace, and introduction to information technology and the basics concepts of science and electronics.

Learning outcome
1. health and safety in the workplace
Assessment criteria – Practical
The learner can: 1.1 demonstrate how to carry out basic first-aid **treatments** 1.2 select correct **equipment** and demonstrate basic fire-fighting techniques for different **types of fire** 1.3 participate in emergency **procedures** 1.4 identify and use **protective clothing** and equipment. 1.5 apply safe working **practices** at all times 1.6 perform risk assessments 1.7 demonstrate the correct **techniques** for manual handling and lifting
Assessment criteria – Knowledge
The learner can: 1.8 state **general requirements** for the observance of safe practice 1.9 state human and environmental **factors** that may lead to an accident 1.10 identify **locational hazards** in the workplace 1.11 state dangers associated with different **materials**, and the necessary **precautions** to be taken 1.12 state **types of fire extinguisher** and suitability for different types of fire 1.13 state relevant first aid **procedures** and **treatments** required in the event of an industrial accident 1.14 state sources of **electrical dangers** and **methods of protection** 1.15 describe the **dangers** from high intensity visible and non-visible light sources in telecommunications

Range
Treatments Shock, electrical shock, bleeding, minor burns, eye injuries **Equipment**

Fire extinguishers (water, CO_2, foam, powder), sand/water bucket, fire blanket, fire hose

Types of fire

Wood/paper fire, oil/spirit fire, electrical fire

Procedures

Raising alarms, safe/efficient evacuation, means of escape, assembly points, roll call, correct return to work, reporting and documenting accidents/injuries, initial first aid procedures

Protective clothing

Overalls, ear defenders, safety boots, gloves, safety helmet (hard hat), particle masks, glasses/goggles/visors

Protective equipment

Safety barriers, hazard notices, permits to work, machine guards, residual current devices, earth sticks, hygiene equipment

Practices

Clean/tidy work areas, removal of waste products, protect surfaces, use of hazard notices and other safety equipment, low level access and lifting equipment

Techniques

Pushing, pulling, lifting, team lifting, carrying

General requirements

Alertness to danger, maintaining personal hygiene, general tidiness, protecting self and others, a knowledge of emergency and hazard reporting procedures, permit- to-work procedures (risk assessment), confined spaces

Factors

Tiredness, carelessness, improper behaviour, lack of training, unguarded or faulty tools and machinery, unsuitable clothing, lack of adequate ventilation

Location hazards

Working in high places, working in confined spaces

Materials

Compressed gases, cryogenic materials, noxious fumes and liquids, explosives, combustible materials

Precautions

PPE (Personal Protective Equipment), storage and disposal of chemicals and equipment

Types of fire extinguisher

Water, CO_2, foam, powder

Need for eye protection

Protection from: sparks, dust, chippings, liquid splashes

Electrical dangers

High voltage, low voltage high current, electromagnetic radiation, damaged/exposed live cables

Methods of protection

Earthing, Residual Current Devices (RCDs), adequate insulation, conduit, isolation, correct fusing

Dangers

Burns, eye damage

Learning outcome
2. introduction to the use of computer technology
Assessment criteria – Practical
The learner can: 2.1 select and load computer applications 2.2 open, **edit**, save and print **data files** 2.3 sort data into numerical or alphabetical order 2.4 exit application software to return to the operating system or graphical user interface(GUI) 2.5 use formatting tools to amend the appearance of documents 2.6 execute single condition searches using appropriate **operators**
Assessment criteria – Knowledge
The learner can: 2.7 identify **main components** of a computer system 2.8 list **peripherals** of a computer system 2.9 define the purpose of software 2.10 state commonly used functions of different software application **packages** 2.11 list **devices** used to input data 2.12 list **devices** used to output data 2.13 state the types of **printers** and their relative characteristics 2.14 state **media** used for storing data and programs 2.15 explain the difference between volatile and non volatile computer memory 2.16 explain why storage disks must be formatted before use

Range
Edit Select cells, edit content of single cells, insert columns and rows, delete columns and rows, Insert formulae (to add, subtract, multiply and divide), replicate formulae in a row or column **Data Files** Word processor, spread sheet, database, bespoke **Operators** Less than, greater than, equal to **Main components** Central Processing Unit(CPU), input devices, output devices, storage devices **Peripherals** Keyboard, mouse, webcam, Visual Display Unit (VDU), printer, CD/DVD/BR - ROM/RW, USB drive **Packages** Spread sheet, word processing, database, computer aided design **Devices** Input devices; keyboard, scanner, barcode reader Output devices; screen, printer, audio systems, remote data logger

Printers Ink jet printer, laser jet printer **Media** CD, DVD, USB

Learning outcome
3. science and electronics
Assessment criteria – Practical
The learner can: 3.1 use **equipment** to demonstrate the effects of **temperature on resistance** 3.2 use **equipment to verify ohm's law** 3.3 use equipment to verify the laws used to determine the total circuit resistance for series and parallel combinations of resistors
Assessment criteria – Knowledge
The learner can: 3.4 identify names and symbols for preferred **si units and prefixes** 3.5 identify **waves** and wave motion 3.6 explain the relationship between velocity (v), frequency (f) and wavelength (λ) as $v = f \times \lambda$ 3.7 state the velocity of an electromagnetic wave in free space 3.8 identify **forms of energy** 3.9 explain principles of conservation of energy and **energy conversion** 3.10 define **scientific terms** used in electronics 3.11 identify international symbols for electrical components on circuit diagrams 3.12 state **effects** of an electric current 3.13 state the difference between primary and secondary cells 3.14 explain the concept of the flow of an electric current 3.15 distinguish between electrical conductors and insulators 3.16 state the relationship between the resistance (*r*) of a conductor, its length (*l*), cross–sectional area (*a*) and resistivity (ρ) 3.17 use ohm's law to solve electrical circuit problems 3.18 state requirements for the **internal resistance of meters** 3.19 identify the potential difference of a source on no–load as its electromotive force (E.M.F.) 3.20 define the internal resistance of a source of E.M.F. 3.21 state the effect of load current on the terminal potential difference 3.22 explain current and voltage relationships in **series circuits** and **parallel circuits** 3.23 identify the **power** (*p*) and **energy** (*w*) **formulae** used in resistive electrical circuits 3.24 state **resistance formulae** for the total value of **resistance combinations** and use them to calculate the total value given the individual values 3.25 explain the meaning of electric (*e*) and magnetic (*h*) fields 3.26 state the principle of operation of **electromagnetic devices** 3.27 describe the structure of an inductor

3.28 describe the structure of an capacitor

3.29 explain that the capacitance (*c*) of a capacitor is directly proportional to the overall surface area (*a*) of the plates and inversely proportional to the distance (*d*) between the plates

3.30 explain that the electric charge (*q*) stored in a capacitor is determined by the capacitance (*c*) and the voltage (*v*) across the plates and is given by $Q = CV$

3.31 state the **capacitance formulae** for the total value of **capacitance combinations** and use them to calculate the total value given the individual values

3.32 state that energy (*w*) is stored in the electromagnetic field of an inductance and the electrical field of a capacitance and give the **storage formulae**

3.33 describe relationships between the **values** of sinusoidal waves

3.34 explain the importance of R.M.S. values

3.35 calculate R.M.S. values given sinusoidal amplitude values

3.36 state that reactance (*x*) is the opposition to the flow of sinusoidal current in either inductance (*l*) or capacitance (*c*) and is measured in ohms

3.37 state the **reactance formulae** for inductance and capacitance

3.38 state the **phase relationships** between voltage and current in resistance, inductance and capacitance

3.39 state that impedance (*z*) is the total opposition to alternating current flow in a series circuit consisting of resistance, inductance and capacitance

3.40 state impedance (*z*) is measured in ohms and is given by the formulae $Z = \sqrt{R^2 + (X_L - X_C)^2}$ or $Z = \sqrt{R^2 + (X_C - X_L)^2}$

3.41 state that series and parallel combinations of inductance and capacitance can be used to form series and parallel tuned circuits

3.42 state that the resonant frequency (f_o) of a tuned circuit can be found from the formula $f_o = 1/2\pi\sqrt{LC}$ where f_o is the frequency in hz, *l* is the inductance in henries (h) and *c* is the capacitance in farads (f)

3.43 state that the applied voltage and current are in phase with each other in resonant tuned circuits

3.44 state the **impedance conditions** for resonant circuits

3.45 describe the structure of an transformer

3.46 state that when a current flows through the primary the resultant magnetic field induces a voltage into the secondary

3.47 state that the value of the voltage induced into the secondary (v_s) is dependent on the voltage applied to the primary (v_p) and the ratio of the number of turns on the secondary (n_s) compared to number of turns on the primary (n_p)

3.48 calculate the secondary voltage of a transformer given the voltage applied to the primary and the number of turns on the primary and secondary windings

3.49 state that a semiconductor has a resistance which is less than that of an insulator but greater than a conductor, and can be 'doped' to form **different material types**

3.50 state that when a junction of different material types is formed, there is a lack of 'majority' current carriers at the junction, which creates the basic structure of a diode

3.51 identify the international symbol for semiconductor diodes and be

able to identify the **terminals**

3.52 state that when a voltage applied to the anode of an ideal diode is positive with respect to its cathode it is forward biased and will conduct

3.53 state that when a voltage applied to the anode of an ideal diode is negative with respect to its cathode it is reverse biased and will not conduct

3.54 state that when a critical reverse bias voltage level of a diode is reached it will break down and conduct heavily

3.55 state that a zener diode operates in the reverse bias condition typically as a voltage regulator

3.56 state the **types of diodes**

3.57 state the **forms of transistor**

3.58 state that the bipolar junction transistor (BJT) is a current-operated device with three **terminals**

3.59 state the **forms of bipolar transistor**

3.60 state that the field effect transistor (FET) is a voltage-operated device with three **terminals**

3.61 state the **forms of FET**

3.62 identify international symbols for transistors and be able to identify the transistor terminals

3.63 state that transistors can be used as electronic switches and amplifiers

3.64 state that complete electronic circuits can be manufactured from a small slice of semiconductor material in the form of integrated circuits.

3.65 state advantages of very large scale integration (VLSI)

3.66 state that linear integrated circuits are available for a variety of **applications**.

3.67 state that digital integrated circuits are available to provide a number of **logic gates** and state their functions

3.68 identify international symbols for logic gates

3.69 identify logical output conditions relative to the input conditions for **logic gates**

Range
Equipment—temperature on resistance Tungsten filament lamp, ammeter, voltmeter, variable resistors, power supply
Equipment to verify Ohm's law Voltmeter, ammeter, a direct current (d.c.) power supply/battery, resistors in series, resistors in parallel
SI units and prefixes Units: metre (m), kilogram (kg), second (s), ampere (A), kelvin (K), voltage (V), joule (J), watt (W), ohm (Ω), henry (H), farad (F) Prefixes: giga (G), mega (M), kilo (k), milli (m), micro (μ), nano (n), pico (p)
Waves Sound waves, electromagnetic waves
Forms of Energy Mechanical (potential and kinetic), heat, chemical, electrical

Energy conversion

Electrical to heat, electrical to chemical, electrical to mechanical, mechanical to electrical, mechanical to heat

Scientific terms

Speed, velocity, acceleration, coulomb, ampere, volt, ohm, 'efficiency' (in terms of input and output energy), amplitude, wavelength, frequency

Effects

Heating, chemical, magnetic

Internal resistance of meters

High for voltmeters, low for ammeters

Series circuits

Current the same in all parts of the circuit, the sum of the voltages is equal to the total applied voltage

Parallel circuits

The sum of the currents is equal to the total current flowing into the network, the voltage is the same in all parts of the circuit

Power and energy formulae

$P = V \times I$, $P = I^2R$, $P = V^2 / R$, $W = V \times I \times t$ where V is the voltage in volts, I is the current in amps, R is the resistance in ohms and t is the time in seconds

Resistance formulae

$R_{\text{SeriesT}} = R_1 + R_2 + R_3 \ldots$, $1/R_{\text{ParallelT}} = 1/R_1 + 1/R_2 + 1/R_3 \ldots$

Resistance combinations

Series, parallel, hybrid

Electromagnetic devices

Electromagnet, relay, electric bell

Capacitance formulae

$C_{\text{ParallelT}} = C_1 + C_2 + C_3 \ldots$, $1/C_{\text{P SeriesT}} = 1/C_1 + 1/C_2 + 1/C_3 \ldots$

Capacitor combinations

Series, parallel, hybrid

Storage formulae

$W = \frac{1}{2}LI^2$ joules for the inductance, $W = \frac{1}{2}CV^2$ joules for the capacitance

Values

Peak, peak–to–peak, root–mean–square (r.m.s.), half–cycle average

Reactance formulae

$X_L = 2\pi fL$, $X_C = 1/2\pi fC$ where L is inductance in henries (*H*), C is capacitance in farads (F) and f is frequency in hertz (Hz)

Phase relationships

Voltage and current are in phase in resistance, voltage leads current by 90^0 in inductance, voltage lags current by 90^0 in capacitance.

Impedance conditions

Series: Impedance (*Z*) a minimum and purely resistive

Parallel: Impedance (*Z*) a maximum and purely resistive

Different material types

N-types which have an excess of electrons

P-types which have a lack of electrons

Terminals

Anode, cathode

Types of diodes.
Rectifier diodes, signal diodes, zener diodes
Forms of transistor
Bipolar Junction Transistor (BJT), Field Effect Transistor (FET)
BJT terminals.
Base, emitter and collector
Forms of bipolar transistor
P-N-P and N-P-N
FET terminals
Source, gate and drain.
Forms of FET
N-channel and p-channel
Applications
Amplifiers, oscillators, comparators etc.
Logic gates
AND, OR, NOT, NAND, NOR, Exclusive-OR

Guidance
3.47 Can be explained with the formula $V_s / V_p = N_s / N_p$
3.51 Learners can use circuit diagrams to identify terminals
3.51, 3.62, 3.68 Learners should be able to draw diode, transistor and logic gate symbols
3.69 Learners should be able to draw truth table for logic gates

Unit 204 Communication Systems and Digital Networks 1

Level:	2
GLH:	130
Aim:	This unit covers areas including information transmission, basic telecommunication systems, optical fibre systems and the principles of radio and television.

Learning outcome
1. information transmission
Assessment criteria – Practical
The learner can: 1.1 source **types of media** used for the communication of information 1.2 perform connectivity **tests** and measurements accurately 1.3 complete accurate connectivity diagnostic reports
Assessment criteria – Knowledge
The Learner can: 1.4 state the meaning of 'telecommunication' 1.5 identify basic **principles** of communications systems 1.6 identify **types** of information carried by telecommunication systems 1.7 state the sources of **interference** 1.8 state sources of **noise** 1.9 list sources of **distortion** 1.10 identify the **properties** of different types of transmission links 1.11 identify methods of **communicating** over transmission links 1.12 state the meaning of 'a signal' 1.13 state the differences between alternating current (A.C.) and direct current (D.C.) signals 1.14 identify the main **terms** used in relation to a signal waveform 1.15 state the difference between analogue and digital signals 1.16 state that analogue signals can be converted into digital signals and vice versa 1.17 state the meaning of signal 'bandwidth' 1.18 identify the differences between baseband and broadband

Range
Types of media Outline knowledge of fibre optic, copper, radio **Tests** Continuity, open circuits, short circuits, crossed connections **Principles** Information source (transmitter), information destination (receiver), transmission medium (channel), line (wired) and radio (wireless) **Types** Information: sound, picture, data Systems: telephone, radio and television **Interference** Electromagnetic radiation and unwanted signals **Noise** Internal, external **Distortion** Non-linearity, harmonics **Properties** Properties: typical attenuation in dB/km, susceptibility to interference, unwanted radiation of signals Fixed links: wired (shielded and unshielded copper multipairs, shielded and unshielded copper twisted pairs, copper coaxial), optical fibre, waveguide Wireless links: wireless (radio), infrared, point-to-point wireless (line-of-sight), geostationary satellite **Communicating** Simplex, duplex , half/semi- duplex, broadcast, symmetric (equal split), asymmetric (unequal split), serial, parallel **Terms** Frequency, amplitude, phase, wavelength, period, velocity, fundamental frequency, harmonics, complex, frequency spectrum

Learning outcome
2. basic telecommunications systems
Assessment criteria – Practical
No practical competence is required
Assessment criteria – Knowledge
The learner can: 2.1 explain how sound waves are converted into electrical signals by means of a **transducer** 2.2 explain how electrical signals are converted into sound waves by means of a **transducer** 2.3 identify **components** used in telephone circuits 2.4 explain the principles of central-battery working 2.5 explain the need for switching in telecommunication networks 2.6 state the formula used to identify the number of links required to fully interconnect users in a network 2.7 explain how public switched telephone network (PSTN) switching is carried out at an exchange 2.8 state that local exchange can be known as the 'central office' 2.9 explain the **terms and units** used in telecommunication systems 2.10 state how **variations** to carrier waves can be used to convey information 2.11 state that a power gain of x db is approximately equal to a factor of y for a range of **values** 2.12 calculate overall gain and/or attenuation of systems given the gain/attenuation of individual stages 2.13 explain how **semiconductor devices** can be used as amplifiers and oscillators in radio transmitters and receivers

Range
Transducer Microphone, earpiece, loudspeaker **Components** Transmitter, receiver, battery, induction coil, cradle switch, calling generator, alerting bell circuit **Terms and units** Gain (dB), attenuation (-dB) **Variations** Amplitude, frequency, phase **Values** x=3 & y=2, x=6 & y=4, x=9 & y=8, x=10 & y=10, x=20 & y=100, x=30 & y=1000, x=60 & y=1000000 **Semiconductor devices** Transistors, linear integrated circuits

Guidance
2.6 formula as follows $l = 1/2[n(n-10]$ – where l is the number of links required to connect n users

Learning outcome
3. optical fibre systems
Assessment criteria – Practical
no practical competence is required
Assessment criteria – Knowledge
The learner can: 3.1 state the advantages and disadvantages of optical fibre compared to copper. 3.2 identify the component parts of an optical fibre used in communication systems 3.3 distinguish between **types** of optical fibre 3.4 identify the **wavelengths** commonly used for optical line systems 3.5 identify **transmitting devices** 3.6 explain the different properties of light emitting diodes (LEDs) and semiconductor laser diodes (SLDs) 3.7 state the **safe working practices** when working with optical fibre and semiconductor laser diodes. 3.8 state reason for **losses** in an optical fibre link 3.9 describe **testing methods** used in fibre optic systems

Range
Types Single-mode, multimode, graded-index, stepped-index **Wavelengths** 850nm, 1300nm, 1550nm and 1625nm **Transmitting devices** LEDs, SLDs **Safe working practices** Statutory requirements, HASAWA/COSHH or relevant national safety standards, laser safety and the Optical Radiation Directive (ORD) **Losses** Connector insertion loss, cabling system losses **Testing methods** Continuity using a visible light source, insertion loss using an infra-red light and power meter and link performance using Optical Time Domain Reflectometer (OTDR) techniques.

Learning outcome
The learner will: 4. principles of radio
Assessment criteria – Practical
The learner can: no practical competence is required
Assessment criteria – Knowledge
The learner can: 4.1 explain how a conductor carrying a high frequency alternating current radiates electromagnetic energy 4.2 state the velocity of radio waves in free space 4.3 state how electromagnetic energy induces an E.M.F. in a conductor 4.4 state the **frequency bands** used in radio 4.5 describe types of **wave propagation** 4.6 state that series and/or parallel combinations of inductance and capacitance, or piezo-electric crystals, can be used for filter circuits 4.7 identify circuit symbols and state the meaning of different **types** of filter circuit. 4.8 state the purpose of an oscillator 4.9 state the purpose of a tuned circuit 4.10 explain the meaning of 'modulation' 4.11 state that modulation may be achieved in a radio transmitter at a low (low-level) or high (high- level) power level. 4.12 describe the types of **modulation** used to communicate audio signals. 4.13 describe the stages of an amplitude-modulated medium frequency **broadcast system** 4.14 define **terms** used in telecommunication systems 4.15 explain the meaning of the different types of **multiplexing** 4.16 Describe the effects of noise and interference on amplitude and frequency-modulated signals

Range
Frequency bands Low frequency (l.f.), medium frequency (m.f.), high frequency (h.f.), very high frequency (v.h.f.), ultra high frequency (u.h.f.) **Wave propagation** Ground wave, space wave, sky wave **Wave bands** Ground wave (surface wave) 30KHz to 300 KHz, Sky wave 300KHz to 30MHz, space wave 3GHz to 30GHz **Types** Low-pass, high-pass, band-pass, band-stop **Modulation** Amplitude, frequency, phase **Broadcast system** Transmission stages: audio frequency, carrier frequency, modulator,

driver, final stage power amplifier, antenna matching stage Reception stages: antenna, radio frequency amplifier, mixer, local oscillator, intermediate frequency amplifiers, demodulator (detector), audio frequency amplifier **Terms** Signal-to-noise ratio, noise figure (noise factor) **Multiplexing** Frequency division multiplexing (FDM), time division multiplexing (TDM)

Guidance
Learners should be familiar with the use of block diagrams to explain the process of radio transmission and reception

Learning outcome
5. mobile radio and cellular telephone systems
Assessment criteria – Practical
The learner can: 5.1 investigate the range of mobile radio and mobile phone systems available 5.2 access sources of reference
Assessment criteria – Knowledge
The learner can: 5.3 identify **users** of private mobile radio (PMR) 5.4 state the frequency bands used for PMR. 5.5 explain the meaning of 'frequency re-use' 5.6 describe how 'frequency re-use' is achieved in mobile radio and cellular telephone systems 5.7 explain why PMR and cellular radio systems are limited to line-of-sight coverage 5.8 explain why PMR systems can use either analogue or digital techniques 5.9 describe the **components of PMR systems** 5.10 explain why in a conventional two-frequency PMR system mobiles cannot hear each other's transmissions. 5.11 describe the **components of cellular radio systems** 5.12 state the **features of cellular telephone systems**. 5.13 explain the purpose of home location registers (HLRs) 5.14 define the term 'roaming' 5.15 explain when 'handover' between base stations takes place. 5.16 identify typical 'cell repeat patterns' 5.17 identify the **factors** that determine maximum and minimum cell sizes 5.18 state the need for cell splitting and/or cell sectorisation 5.19 identify **components of 3g networks**

Range
Users Emergency services, public utilities, taxis **Components of PMR systems** Base station, mobiles **Components of cellular radio systems** Number of linked cells, each with a base station. **Features of cellular telephone systems** Frequency bands, use of analogue or digital techniques, analogue being replaced by digital, can transmit and received on all allocated channels, identification with base station **Factors** Geographical location, population size **Components of 3G networks** Wideband Base Transceiver Station (WBTS), Radio Network Controller (RNC), Serving General Packet Radio Service Support Node (SGSN), Gateway General Packet Radio Service Support Node (GGSN), Mobile Switching Centre (MSC), Visitor Location Register (VLR), Home Location Register (HLR)

Guidance
Learners should be familiar with the use of diagrams to describe mobile telecommunication systems and 3G networks

Learning outcome
6. television
Assessment criteria – Practical
No practical competence is required
Assessment criteria – Knowledge
The learner can: 6.1 describe the basic principle of operation of **television equipment** 6.2 explain why a monochrome picture can be regarded as being composed of small elements of differing brightness 6.3 describe the additive **colour mixing process** for television 6.4 state the purpose of field and line scans on the screen of a cathode ray tube 6.5 state typical line and field scan periods 6.6 state the different levels of definition as depicted by scan lines 6.7 state the difference between interlaced an progressive scan 6.8 explain how plasma and liquid crystal display (LCD) flat-panel tvs convert an interlaced source to a progressive scan for display 6.9 describe the basic principle of moving picture experts group (mpeg) 6.10 explain how a television camera works

Range
Television equipment Cathode ray tube (c.r.t.), monochrome (black and white) television broadcast system, LCD flat-panel TVs **Colour mixing process** Three primary colours red, green and blue can be mixed in an additive manner to produce the three complementary colours cyan, magenta and yellow. In between colours can be provided by various levels of the primary colours.

Learning outcome
7. public switched telephone networks (PSTNS)
Assessment criteria – Practical
No practical competence is required
Assessment criteria – Knowledge
The learner can: 7.1 identify the **components** of a basic telephone instrument circuit 7.2 state that telephone networks rely mainly on digital techniques for long and short distance working 7.3 describe the operation of a dual tone multi-frequency (DTMF) keypad 7.4 state the purpose of concentrators and multiplexers in telephone networks 7.5 identify the **structure** of the public switched telephone network (PSTN) 7.6 state that the PSTN is an example of a circuit-switched network 7.7 identify the telephone numbering format for local, national and international calls 7.8 state how analogue voice signals can be converted to digital signals by means of pulse code modulation (PCM) 7.9 identify the **stages** of a pulse code modulator 7.10 identify the purpose of a low-pass filter 7.11 explain the function of quantisers 7.12 calculate the bit rate for a **32-channel PCM** time division multiplexing system 7.13 state the function of time slots 0 and 16 in the 32-channel PCM time division multiplexing system 7.14 state the function of the regenerator in PCM networks 7.15 state the difference between European and the United States 1st, 2nd and 3rd order multiplexing systems for the **plesiochronous** digital hierarchy (PDH) 7.16 state the basic concepts of a stored program control (SPC) exchange 7.17 identify the need for space and time switching in digital telephone networks 7.18 state the main function of a digital switching subsystem (DSS) in a system x exchange 7.19 identify the basic differences between the integrated services

digital network (isdn) and the PSTN

7.20 state that digital 'backbone' networks use the synchronous digital hierarchy (SDH)

7.21 identify that a synchronous optical network (SONET) is a subset of the SDH

Range

Components

Speaker, transmitter, bell, battery, ringing circuit (capacitor) for local battery telephones, for central battery phones the battery is relocated into the exchange

Structure

Local loop, street cabinets/footway boxes, distribution points, analogue local exchange or digital Remote Concentrator Units (RCUs), Digital Cell Centre Exchange (DCCE), Digital Main Switching Units (DMSUs)

Stages

Low-pass (anti-aliasing) filter, sample-and-hold, sampling frequency (clock), quantiser, encoder.

32-channel PCM

Typical sampling frequency for voice systems (8 kHz).

The number of bits normally assigned for voice systems (8).

The bit rate normally assigned for voice systems (64 kb/s).

Plesiochronous

Compare the bit rates, the effective number of channels and control channels carried for each of the first three levels of European and United States PDH multiplexing.

Learning outcome

8. digital networks and data communication

Assessment criteria – Practical

No practical competence is required

Assessment criteria – Knowledge

The learner can:

8.1 state the purpose of a data network

8.2 state the advantages of digital communication over analogue methods

8.3 distinguish between 'bits', 'bytes' and 'nibbles'

8.4 describe the meaning of 'serial' and 'parallel' working

8.5 state the meaning of bit error rate (BER)

8.6 identify typical BER rates for different **transmission media**

8.7 identify the difference between automatic repeat request (ARQ) and the forward error correction (FER) methods of dealing with errors

8.8 describe methods of **error checking** in digital communication networks

8.9 describe the **features of computer communication**

8.10 state the advantages and disadvantages of transmitting data by serial and parallel methods

8.11 identify applications for serial and parallel data communication

8.12 describe the **transmission techniques** used for computer

communication

8.13 state how remote computers **access other networks**

8.14 identify types of **leased lines**

8.15 explain the purpose of 'modems'

8.16 describe the basic modulation techniques used by modems

8.17 state the characteristics of **switching** used in data networks

8.18 describe the characteristics of methods of using **packet switched networks**

8.19 identify the itu-t protocol for packet switching

8.20 describe the international standards organisation (ISO) seven layer open systems interconnection (OSI) model

8.21 identify the **categories** of computer networks

8.22 identify the basic **topologies** of computer networks

8.23 state the methods of gaining **access** to computer networks.

8.24 identify the **transmission media** used for local area networks

8.25 state the **hardware** used on local area networks

8.26 explain the term 'broadband' in context to radio communications and internet

Range

Transmission media

Copper, optical fibre, radio systems

Error checking

Loop-back, parity

Features of computer communication

Protocols define the rules of procedure, computer information is sent in a binary format using an agreed transmission code, two methods of transmitting data - serial and parallel

Transmission techniques

Asynchronous, synchronous

Access other networks

Leased lines, 'dial-up' (switched) lines

Leased lines

'kilostream' (64 kb/s), 'megastream' (2.048 Mb/s)

Switching

Circuit, message, packet

Packet switched networks

Connectionless (datagram), connection oriented (virtual circuit)

Categories

Local Area Networks (LANs), Metropolitan Area Networks (MANs), Wide Area Networks (WANs)

Topologies

Star,bus, ring

Access

Carrier Sense Multiple Acess with Collision Detection (CSMA/CD), token passing

Hardware

Hubs, switches, file servers, repeaters, bridges, routers, gateways

Guidance
8.19 - 20 – Learners should have an understanding of their regional standards and protocols of telecommunications systems

Unit 205 Mathematics

Level:	2
GLH:	60
Aim:	The aim of this unit is to enable the learner to solve mathematical, scientific and associated problems at the technical level, gain the underpinning mathematical knowledge for communication systems and digital networks and provide an educational base for study at a higher level.

Learning outcome
1. electronic calculators and si units
Assessment criteria – Practical
The learner can: 1.1 use an electronic calculator to perform **calculations**
Assessment criteria – Knowledge
The learner can: 1.2 identify appropriate number of decimal places for answers to calculations 1.3 estimate approximate values of arithmetic expressions 1.4 identify **units** for answers to physical problems using common **prefixes**

Range
Calculations Addition, subtraction, division, multiplication, powers, roots, reciprocals logarithms ($\log_{10}$ and $\log_e$), exponentials of numbers, sines, cosines, tangents of angles, use inverse function to find the angle when given the corresponding sine/cosine/tangent **Units** Length, mass, time, electric current, thermodynamic temperature, velocity, acceleration, density, frequency, angle, force, pressure, energy, work, power, resistance, voltage, capacitance, inductance, decibels **Prefixes** G, M, k, m, µ, n and p

Guidance
Resources - Learners should have access to a scientific notation calculator with capability for the range of calculations required

Learning outcome
2. algebra
Assessment criteria – Practical
No practical required
Assessment criteria – Knowledge
The learner can: 2.1 factorise expressions by grouping and extraction of common factors. 2.2 distinguish between an algebraic expression, an equation and an identity. 2.3 maintain the equality of a given equation whilst applying arithmetic operations. 2.4 solve linear equations in one unknown including those involving brackets and fractions. 2.5 form and solve linear equations. 2.6 solve simultaneous linear equations in two unknowns using different **methods** 2.7 evaluate formulae by substitution of data 2.8 transpose different types of formulae

Range
Methods Substitution, elimination **Different types of formulae** Those in which the subject is equal to an expression whose terms are connected by + or –, those in which the subject is equal to an expression composed of two or more factors, those that contain a root or power, those in which the subject appears in more than one term.

Guidance
Guidance 2.7 Learners should be aware o f a range of typical engineering formulae for example, V = IR, v = u + at, A = πr^2, ρ = m/V, W = $\frac{1}{2}CV^2$, t = $2\pi\sqrt{l/g}$, $z^2 = x^2 + y^2$, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

Learning outcome
3. laws of indices
Assessment criteria – Practical
The learner can: No practical required
Assessment criteria – Knowledge
The learner can: 3.1 perform calculations applying **laws of indices** 3.2 state $a^0 = 1$ for all values of a. 3.3 apply rules of **laws of indices** where m and n are negative integers. 3.4 apply rules of **laws of indices** for fractional indices 3.5 evaluate expressions that combine different **types of indices**

Range
Laws of indices – $a^m \times a^n = a^{m+n}$ $\frac{a^m}{a^n} = a^{m-n}$ $\left(a^m\right)^n = a^{m \times n}$ $a^{\frac{1}{n}} = \sqrt[n]{a}$ and $a^{\frac{m}{n}} = \sqrt[n]{a^m}$ where m and n are positive integers. **Types of indices –** positive, negative, fractional

Guidance
3.1 – 3.4 Typical examples of the application of laws of indices such as $a^2b^3c \times ab^2c^6 = a^3b^5c^7$, $\frac{x^5y^2z}{x^2yz^4} = x^3y\,z^{-3}$ or $\frac{x^3y}{z^3}$, $\left(mn^2\right)^3 = n^3m^6$, $\sqrt[3]{a^4} = a^{\frac{4}{3}}$

Learning outcome
4. geometry
Assessment criteria – Practical
The learner can: no practical required
Assessment criteria – Knowledge
The learner can: 4.1 use formulae to calculate areas and perimeters of **plane figures** 4.2 use formulae to calculate the surface area and volume of **common solids** 4.3 identify **components of a circle** 4.4 solve problems relating to circumference, radius and diameter of circles 4.5 state the **property** of the angle between a tangent and the radius of a circle at the point of contact 4.6 define the radian in terms of π 4.7 convert degree measure to radians and vice versa

Range
Plane figures Triangle, square, rectangle, parallelogram, circle, semicircle **Common solids** Cube, prism, cylinder, pyramid, cone, sphere **Components of a circle** Radius, diameter, circumference, area, chord, tangent, secant, sector, segment, arc **Property** Right angle

Learning outcome
5. trigonometry
Assessment criteria – Practical
The learner can: no practical required
Assessment criteria – Knowledge
The learner can: 5.1 state the angle sum of triangles 5.2 identify **types of triangle** 5.3 identify complementary angles 5.4 calculate the length of any third side of a right angled triangle using pythagoras' theorem 5.5 state that any triangle whose sides are in the ratio 3:4:5 forms a right-angled triangle 5.6 compare triangles for similarity and congruency 5.7 determine an unknown side or an angle of a second triangle applying the principles of similarity and congruency 5.8 define **trigonometric ratios**

5.9 solve problems involving right angled triangles using **trigonometric ratios**

Range
Types of triangle – acute-angled, right-angled, obtuse-angled, equilateral, isosceles **Trigonometric ratios** - sine, cosine and tangent

Learning outcome
6. graphs
Assessment criteria – Practical
The learner can: no practical required
Assessment criteria – Knowledge
The learner can: 6.1 identify suitable scales for graphs 6.2 plot graphs using experimental data 6.3 plot graphs of equations by forming a data table and plotting the points 6.4 identify values from graphs and interpolate immediate values between points 6.5 determine the intercept of a straight line on the y-axis by extrapolation 6.6 determine the gradient of a straight-line graph 6.7 state the law of a straight-line graph from values determined 6.8 determine the roots of a quadratic equation from the intersections of the graph with the x-axis 6.9 solve graphically a pair of simultaneous equations in two unknowns

Guidance
6.2 Typical examples of Equations – y = mx + c, $y = \frac{1}{x}$, $y = x^2$

Learning outcome
7. number systems
Assessment criteria – Practical
The learner can: no practical required
Assessment criteria – Knowledge
The learner can: 7.1 express decimal numbers in binary form and binary numbers in decimal form 7.2 perform calculations involving addition of binary numbers 7.3 define the octal number system 7.4 convert decimal numbers to binary via octal form 7.5 define the hexadecimal number system 7.6 convert hexadecimal numbers to decimal and vice versa 7.7 convert from binary form to hexadecimal and vice versa

Guidance
Examples of Number system conversion – converting 57 to binary, 10101_2 to decimal, $10111_2 + 100111_2$, 572 to binary via octal, $2C_{16}$ to decimal, 110100101_2 to hexadecimal

Learning outcome
8. basic statistics
Assessment criteria – Practical
The learner can: no practical required
Assessment criteria – Knowledge
The learner can: 8.1 record data by means of a tally chart 8.2 record results in the form of a frequency table 8.3 represent information from frequency tables in **pictorial form** 8.4 arrange ungrouped data in rank order and determine the median and modal values 8.5 construct a cumulative frequency graph from a given frequency distribution 8.6 calculate arithmetic means for **data** 8.7 estimate modal values of grouped data using histograms 8.8 determine the median, quartiles, deciles and percentiles from cumulative frequency data 8.9 define standard deviations of data as a measure of dispersion 8.10 calculate values of standard deviation for ungrouped data and grouped data 8.11 calculate ranges and semi-interquartile ranges as simple alternative measures of dispersion

Range
Pictorial form Pie charts, bar charts, line graphs **Data** Grouped, ungrouped

Learning outcome
9. logarithms and indicial equations
Assessment criteria – Practical
The learner can: no practical required
Assessment criteria – Knowledge
The learner can: 9.1 define logarithms to any base 9.2 convert indicial equations to logarithmic relationships and vice versa 9.3 deduce **laws of logarithms** for any base b 9.4 explain that $log_b 1 = 0$ and $log_b b = 1$ 9.5 explain that as x → 0, $log_b b \rightarrow$ -∞ 9.6 apply **laws of logarithms** to calculations 9.7 state the base of e of natural logarithms 9.8 define natural (napierian) logarithms ($log_e x$ or $ln\, x$) 9.9 evaluate expressions and solve equations using natural logarithms 9.10 change the base of numbers using laws of powers and where the index is in algebraic form 9.11 solve indicial equations where the indices are linear or quadratic in one unknown

Range
Laws of logarithms $log_b(xy) = log_b x + log_b y$ $log_b\left(\frac{x}{y}\right) = log_b x - log_b y$ $log_b\left(x^a\right) = a\, log_b x$

Guidance
9.6 Typical calculations – for example, log 5 + log 7 = log 35, log 16 – log 2 = log 8, 2 log 3 = log 9 9.9-11 Typical equations – for example, $2^x = 7$, $4e^{-2x} = 9$, $log\left(x^2 - 3\right) - log\, x = log\, 2$

Unit 208 Constructing, testing and fault finding electronic circuits (elective)

Level:	2
GLH:	60
UAN:	L/503/0203
Credit value:	7
Aim:	This unit is concerned with the processes and equipment essential to building and testing electronic circuits. The topics covered will enable the learner to collect, read and interpret information, plan and prepare for electronics activities, and state how to identify electronic components. The learner will also be able to perform circuit and diagnostic checks, and make simple deductions from the results of these checks.

Learning outcome
The learner will: 1. be able to prepare for building and testing of electronic circuits
Assessment criteria
The learner can: 1.1 define **units of measurement** and their multiples and sub-multiples for electrical quantities and components 1.2 describe the **V, I and R relationships** for simple dc circuits 1.3 identify electronic components and their circuit symbols, values and **ratings** 1.4 identify **semiconductor components**, and their circuit symbols 1.5 state typical applications for **primary and secondary cells** 1.6 state typical applications for **input and output devices** 1.7 identify **heat sinks**, and explain their function 1.8 select and use information from **common sources** used in the electronics industry 1.9 describe the basic **function of components** within a circuit 1.10 describe how to plan **work activities** listing **tools and components** required 1.11 identify **potential hazards** relating to a given task and **safety measures** that could be applied.

Range
Units of measurement: ampere, volt, ohm, Watt, coulomb, Farad,

Henry, pico, nano, micro, milli, Kilo, Mega, Giga, Tera, resistor colour code (4 band)

V, I and R relationships: series resistor circuits, parallel resistor circuits, series / parallel resistor circuits, Ohms Law, EMF, potential difference

Electronic components:

- resistors – carbon film, carbon composition, metal oxide, wirewound, surface mount, variable, fusible
- capacitors – ceramic, paper, polypropylene, mica, electrolytic, tantalum, surface mount, variable
- inductors – air core, ferrite core, iron core
- transformers – power, rf
- switches – single pole, double pole, relay
- fuses – mains, quick blow, anti-surge, time delay, solid state
- indicating devices – filament lamp, LED, panel mounting devices

Ratings: resistor power, resistor tolerance, capacitor voltage, filament lamp power

Semiconductor components: signal diode, power diode, bridge rectifier (encapsulated), zener diode, LED, photo diode, bi-polar transistor, unijunction transistor, photo transistor, MOSFET, opto-coupler, integrated circuits

Primary and secondary cells: zinc carbon, zinc chloride, silver oxide, lithium, nickel cadmium, nickel metal hydride, lead acid

Input and output devices: transducers, transformers, sensors, actuators, stepper motors, display devices

Heat sinks: convection cooled, fan cooled, water cooled, heat sink compound

Common sources: circuit diagrams, block diagrams, layout diagrams, equipment reference manuals, data sheets, practical tests

Function of components: resistors, capacitors, inductors, switches, fuses, diodes, transistors, transducers, transformers, sensors, actuators, stepper motors, display devices

Work activities: building, testing, repairing

Tools and components: screwdrivers, pliers, cutters, spanners, clamps, soldering tools, de-soldering tools, extraction / insertion tools, solvent cleaners, all components listed in range statements above

Potential hazards: using hand tools, soldering equipment, solder splash, solvents, high voltages,

Safety measures: isolation transformers, RCD protection, rubber matting, anti-static wrist / ankle straps / clothing, solder fume extraction

Learning outcome
The learner will: 2. be able to test, fault find and repair electronic equipment.
Assessment criteria
The learner can: 2.1 describe **preparatory activities** necessary prior to testing electronic equipment 2.2 identify **test instruments**, and their applications 2.3 describe methods for **connection / disconnection** of connectors

and test probes

2.4 state common components / items that can reveal fault conditions through **visual inspection**

2.5 state **terminology** used in fault diagnosis

2.6 identify and describe **typical faults** in electronic equipment

2.7 apply **typical fault diagnosis techniques**

2.8 describe **common factors** that determine the method of repair

2.9 describe **methods for recording** symptoms, faults, and action taken.

Range

Preparatory activities: safety checks, test instrument calibration check, setting up of test instruments, removal of equipment covers / casings, mains supply isolation, cleaning of modules / components

Test instruments: multimeter, insulation resistance tester, continuity tester, oscilloscope, storage scope, signal generator, signal injector, variable dc power supply

Connection/disconnection: test probes, instrument sensors, risk of arcing, risk of shorting, risk of circuit loading

Visual inspection:

- fluid components – pipework, air / fluid lines, couplings, seals, sensors
- electrical components – instrument needles, cables, connectors
- electronic components – printed circuit boards, component / wiring positioning, component values, spillage, burning / scorching, blown fuses
- mechanical components – damaged / overheated equipment housings, physical damage, presence of foreign bodies

Terminology: symptom, fault, cause

Typical faults: leaking – pipework, air lines, fluid lines, couplings, seals, damaged or faulty – sensors, instrument needles, electrical cables, electrical connectors, printed circuit boards – breaks, spillages, burnt/charred components, reduced or no functionality

Fault diagnosis techniques: input to output checks, half split method, injection and sampling, circuit/component isolation, component/unit substitution, use of symptom(s) to determine nature of fault, correct selection of instrument, identification of test points, connection methods for test instruments, application of circuit / layout diagrams, comparison of actual readings to specified readings, interpretation of results

Common factors: time versus cost of module/unit, serviceability of module/unit, availability of individual components, possibility of damage to other components / modules

Methods for recording: paper based, electronic

Learning outcome

The learner will:

3. be able to construct new, and identify faults on existing, electronic equipment

Assessment criteria

The learner can:

3.1 state briefly the function of **electronic components** in circuits
3.2 describe methods for connecting/orientating **electronic components** in circuits
3.3 identify common **connection and termination devices** employed in electronic circuits
3.4 use correct **assembly methods** for circuit boards
3.5 describe component **insertion methods**
3.6 use correct methods for **preparing/fixing wiring and cables**
3.7 describe methods for avoidance of **static damage to components / circuit boards** whilst handling
3.8 list the applications for different **types of solder**
3.9 identify different types of **soldering/de-soldering equipment**
3.10 apply **effective soldering practices**
3.11 describe methods for the **removal of devices** from circuit boards
3.12 describe the **values of a.c. waveshapes**
3.13 use **test instruments** to take measurements on electronic circuits
3.14 relate test results to **values** given on circuit information
3.15 explain the importance of verifying **PSU** (power supply) **functionality** during fault finding
3.16 **restore equipment** to safe working order following repair / investigation
3.17 follow good working practices throughout the construction / fault location process.
3.18 **restore work area** using the correct procedure for the disposal of waste.

Range

electronic components:

- resistors – carbon film, carbon composition, metal oxide, wirewound, surface mount, variable, fusible
- capacitors – ceramic, paper, polypropylene, mica, electrolytic, tantalum, surface mount, variable
- inductors – air core, ferrite core, iron core
- transformers – power, rf,
- switches – single pole, double pole, relay
- fuses – mains, quick blow, anti-surge, time delay, solid state
- indicating devices – filament lamp, LED, panel mounting devices
- semiconductors – signal diode, power diode, bridge rectifier
- (encapsulated), zener diode, LED, photo diode, bi-polar transistor,
- unijunction transistor, photo transistor, MOSFET, opto-coupler,
- integrated circuits
- wiring – wire links, jumper links, cables, connectors

Connection and termination devices: plug and socket, crimp, solder pin, terminal screw

Assembly methods: component orientation, component mounting, avoidance of component damage, routing and grouping of wiring, marking of flying leads / connectors, cable ties and clamps

Insertion methods: manual insertion methods, automated insertion methods

Preparing / fixing wiring and cables: selection of wires / cables,

stripping, tinning, termination, dressing, avoidance of electronic interference, avoidance of mechanical damage

Static damage to components / circuit boards: anti-static wrist / ankle straps, use of conductive mats, use of conductive bags / containers, equipotential bonding of work area, component / board transportation, static warning labels

Types of solder: rosin free, autosol (high speed), low residue no clean, hydro flux

Soldering / de-soldering equipment: 230 V a.c. high wattage iron, low voltage iron, gas iron, hot air gun, flow solder process, de-soldering pump, solder wick

Effective soldering practices: component handling, solder selection, cleaning of joint areas, mechanically and electrically sound joints, sufficient solder application, joints free of splatter, short circuits and spikes

Removal of devices: PCB – single sided, double sided, multi-layer components – discrete, multi-pin, surface mount

Values of a.c. waveshapes: periodic time, frequency, peak to peak, peak, average, RMS (root mean squared)

Test instruments: multimeter, oscilloscope, function generator

Values: d.c. voltages, d.c. currents, resistance, a.c. waveshapes,

PSU functionality: output voltage(s), ability to deliver required load current(s), effects of overload trip circuits / devices

Guidance

Restore equipment: all connectors re-made, all safety components / devices correctly installed, all cables / wiring harnesses correctly fixed, equipment free of foreign bodies, all covers re-fitted and correctly secured

Restore work area: work area is tidy and free of hazards, safe working practices are observed, work area is left clean and tidy, tools /test instruments are returned to safe storage

Unit 301 Fundamentals of electronic communication 2

Level:	3
GLH:	85
Aim:	This unit covers areas including Boolean algebra, combinational logic gates and relaxation oscillators, terminology of communication networks and the nature, sources and effects of noise on telecommunications.

Learning outcome
1. boolean algebra, combinational logic gates and relaxation oscillators
Assessment criteria – Practical
practical not required
Assessment criteria – Knowledge
The learner can: 1.1 explain **laws of boolean algebra** and their relationship with switch circuits for logic functions 1.2 explain functions of **logic gates** and construct their truth tables 1.3 identify the British standard (BS) and American military standard (mil) symbols for **logic gates** 1.4 construct truth tables for combined logic functions 1.5 use truth tables to derive boolean expressions for the output function in terms of the inputs 1.6 derive not and and or functions using nand or nor logic gates 1.7 determine boolean expressions from logic networks and vice versa 1.8 state de morgans theorem 1.9 prove de morgans theorem using truth tables 1.10 explain the relevance of de morgans theorem in logic circuit design 1.11 minimise combined logic functions using boolean algebra and/or karnaugh map 1.12 distinguish between **relaxation and sine wave oscillators** 1.13 identify symbols for **multivibrators** 1.14 explain using waveform diagrams, the operation of multivibrators 1.15 explain **applications for multivibrators** 1.16 explain how a **bistable** may be implemented using either nand or nor gates 1.17 construct truth tables for **bistable** multivibrators

Range
Laws of Boolean algebra: $A.B = B.A, \quad A.1 = A, \quad A.0 = 0, \quad A.A = A, \quad \bar{A} = 0, \quad \bar{\bar{A}} =$ $A + B = B + A, \quad A + 1 = 1, \quad A + 0 = A, \quad A + A = A, \quad A + \bar{A}$ $A.B.C = A(B.C) = (A.B)C$ $A + B + C = (A + B) + C = A + (B + C), \quad A.(B + C) = A.B + A.C$ $A + B.C = (A + B).(A + C)$ **Logic gates** AND, OR, NOT, NOR, NAND **Relaxation and sine wave oscillators** Output waveforms, component parts **Multivibrators** Astable, monostable, bistable **Applications for multivibrators** pulse generation, switch de-bouncing, pulse stretching, memory, latch **Bistable** Constructed using NAND or NOR elements, truth table for both circuits

Guidance
Knowledge can be demonstrated through computer simulation and/or laboratory practical – e.g. “National Instruments Multisim”, “Electronics Workbench” or “Crocodile Clips” Guidance 1.4 – Learners should be able to construct truth tables for up to three inputs Guidance 1.10 – minimisation can be achieved using a truth table, Boolean expression or gate diagram

Learning outcome
2. terminology and requirements of simple telecommunication networks
Assessment criteria – Practical
practical not required
Assessment criteria – Knowledge
The learner can: 2.1 explain the **basic components** required by a telecommunication system. 2.2 explain **requirements** needed to prepare a signal for transmission 2.3 explain the **factors that affect signals** during the communication process and identify their **sources** 2.4 describe the main features of **signal waveforms**. 2.5 describe the **properties** of different types of **transmission links** 2.6 describe **methods of communicating** over a transmission link 2.7 explain why different forms of transmitted **signals use different bandwidths** 2.8 explain the difference between a repeater and an amplifier 2.9 explain the purpose of repeating a signal along a transmission line 2.10 describe the operation of 2 – 4 wire converters 2.11 explain the advantages of 4-wire working over 2-wire working 2.12 describe how 4-wire circuits can become unstable

Range
Basic components Source, transmitter, receiver, destination, medium **Requirements** D.C Power supplies, amplification, analogue to digital conversion, conditioning/processing, coding/de-coding **Factors that affect signals** Gain (amplification), loss (attenuation), distortion (shape), frequency, interference, noise **Sources** Amplifiers, attenuation factors, non linearity of components, limited bandwidth, radiated interference. **Signal waveforms** Amplitude, frequency, phase, wave-shape, complex (consisting of a combination of sinusoidal waveforms) **Transmission link properties** Typical attenuation in dB/km, susceptibility to interference, unwanted radiation of signals. **Transmission links** Fixed Links (e.g. Wired, Optical Fibre etc.) Mobile Links (e.g. wireless (radio), non-geostationary satellite etc.) **Methods of communicating** Simplex, Duplex, Half/Semi-Duplex, broadcast, serial, parallel. **Signals use different bandwidths** *Frequency ranges of voice, music and video. Bandwidths for commercial speech, hi-fi music, sound broadcasting, monochrome and colour t.v.*

Guidance
2.9 Learners can use block diagrams, to aid description of operation of 2 – 4 wire converters. Producing complex circuit diagrams is not required.

Learning outcome
3. the nature, sources and effects of noise on telecommunications and the use of decibels as the unit of measurement
Assessment criteria – Practical
practical not required
Assessment criteria – Knowledge
The learner can: 3.1 state the benefits of using logarithmic units in telecommunication systems and networks 3.2 derive the power gain or loss (attenuation) of a network or system using 'blackbox' models 3.3 define the decibel (DB) and DBM 3.4 describe the use of DBM in system calculations 3.5 define voltage and current gain/loss in DB 3.6 derive the condition for correct use of **gain formulas** in DB 3.7 calculate overall and stage gains for systems. 3.8 define noise and its effect on communication systems 3.9 explain the **sources** of internal and external noise 3.10 list **types of noise** which result from **sources** 3.11 distinguish between white noise and impulse noise 3.12 define signal to noise ratio and explain its significance 3.13 explain why signal to noise ratio is normally stated in DB 3.14 solve problems relating to signal/noise ratio 3.15 define noise **characteristics** 3.16 calculate thermal (johnson) noise

Range
Gain formulas Power, voltage, current. Relate to input and output resistance. **Sources** Internal Noise - Change in component characteristics with temperature, operation of semiconductor devices. External Noise - Natural (e.g. lightning discharges, solar activity) artificial/man-made (e.g. ignition systems, rotating machinery) **Types of noise** Internal (thermal/Johnson, shot, flicker) External **Characteristics** Noise factor (F), noise figure (NF), noise temperature (T_n), thermal (Johnson) noise

Guidance
3.14 Learners should be able to solve problems using formulae for example – S/N Ratio (dB) = 10 log (Signal Power / Noise Power) and S/N Ratio (dB) = 20 log (Vsignal/Vnoise) 3.16 using formula $v_n = \sqrt{(4kTBR)}$ volts

Learning outcome
4. characteristics of transmission lines and cables used for telecommunication
Assessment criteria – Practical
practical not required
Assessment criteria – Knowledge
The learner can: 4.1 describe **effects of metallic cables** on analogue and digital signals 4.2 explain **primary coefficients** of a transmission line 4.3 explain why r and c are the most significant primary coefficients in unloaded cables 4.4 define **terminology** relating to transmission lines 4.5 describe the shape of **response curves** for coaxial **cable conditions** 4.6 explain the effect of **cable characteristics** on a signal transmission 4.7 explain the terms used in relation to **distortion effects** on a rectangular pulse 4.8 explain the relationship between rise-time and bandwidth of a single stage low pass *rc* filter. 4.9 describe the propagation of an electromagnetic wave along a twin transmission line 4.10 explain why negligible radiation occurs from coaxial cable 4.11 describe the equivalent circuit of a loss-free transmission line and state the formula for z_o. 4.12 explain the effects of terminating load conditions. 4.13 explain that z_o is the ratio of voltage to current for a wave propagated on a line which is terminated in z_o 4.14 describe termination conditions that cause total reflection. 4.15 describe effects of reflected waves on pulse systems. 4.16 distinguish between travelling and standing waves and explain how reflection produces a standing wave. 4.17 describe how **conductor and spacing dimensions** of open-wire lines and coaxial cables affect the value of characteristic impedance 4.18 state typical values of z_o for open-wire lines and coaxial cables

Range
Effect of metallic cables Attenuation, distortion, bandwidth, bit rate **Primary coefficients** Explanation of the terms resistance (R) and capacitance (C), conductance (G), inductance (L) should relate to the physical conditions of the transmission line that make up these coefficients. **Terminology** Characteristic impedance (Zo), attenuation coefficient (α), phase-change coefficient (β) **Response curves** Attenuation/frequency and delay/frequency **cable conditions** Unloaded, loaded cable **Cable characteristics** Analogue bandwidth, digital bit rate. **distortion effects** Rise time, 5 sag **Definition characteristic impedance Zo** Both standard definitions should be given, Zo of a line as equal to the value of the terminating load that causes no reflection and hence absorbs maximum power and Zo is the input impedance for an infinite length of line **Conductor and spacing dimensions** Z_o for coaxial cable given by: $Zo = \frac{138}{\sqrt{\varepsilon}} \times log\left(\frac{D}{d}\right)\Omega$ Z_o for open wire line given by: $Zo = \frac{276}{\sqrt{\varepsilon}} \times log\left(\frac{D}{r}\right)\Omega$

Guidance
4.2 Learners should sketch an equivalent circuit for a section of line to aid explanation of the four primary coefficients 4.8 The learner can find the relationship $t_r \cong 2.197\tau$ by using equation, $v_t = V_o(1 - e^{-\frac{t}{\tau}})$. Then by substitution into $\tau = RC = \frac{1}{2\pi f_H}$ the required relationship $(RISE\ TIME)t_r \cong \frac{0.35}{Bandwidth}$. Note 1: The device is subjected to a rectangular pulse. Note 2: Since Bandwidth = $f_H - f_L$, if $f_L = 0$, then Bandwidth = f_H. Note 2: Can be used to determine Bandwidth necessary for a pulse with a particular Rise Time. 4.14 Learners should be able to provide simple descriptions using voltage conditions, for a short-circuited termination and current conditions for open-circuited termination. 4.15 Learners can use a diagram to show how a standing wave is formed. 4.17 Characteristic impedance formulas that relate to cable dimensions should be used in descriptions

Learning outcome
5. effects of capacitors and inductors in filters and oscillators
Assessment criteria – Practical
practical not required
Assessment criteria – Knowledge
The learner can: 5.1 describe filter **frequency response characteristics** indicating the 3db frequency 5.2 identify filter symbols used in network diagrams 5.3 identify types of filter from **frequency response characteristics** 5.4 determine **rate of attenuation** from **frequency response characteristics** 5.5 describe effects of passing a **complex wave** through low-pass and high-pass filter circuits. 5.6 describe resonant and non-resonant **current flow** in a parallel LC circuit 5.7 identify **formulas** used to calculate typical values for the resonant frequency and dynamic impedance of a parallel LC circuit 5.8 explain the relationship between voltage gain and resistive load in a single stage amplifier 5.9 explain that an amplifier using a parallel LC circuit as a load will have maximum voltage gain at the resonant frequency. 5.10 describe how a fraction of the voltage across the load can be used to provide the amplifier input signal 5.11 describe a radio frequency (R.F.) oscillator as a self-driven amplifier with a parallel LC circuit as the load 5.12 describe the tuning of R.F. oscillators by the adjustment of l and c

Range
Frequency response characteristics Low-pass, high-pass, band-pass, band-stop **Rate of attenuation** 6dB/octave / 20dB/decade single-pole RC filter circuits only **Complex wave** Square wave through low-pass, triangular wave through high-pass with suitable time constant chosen to indicate wave-shapes clearly. **Current flow** Description of I_C, I_L and I_{SUPPLY} either side of, and at, the resonant frequency **Formulas** Resonant frequency = $\frac{1}{2\pi\sqrt{LC}}$ Hz Dynamic impedance = $\frac{L}{CR}$ ohms

Guidance
5.5 Learners should use diagrams to show the effects of passing a complex wave through low-pass and high-pass filter circuits.

Learning outcome
6. principles of communicating information by varying the characteristics of high frequency waveform
Assessment criteria – Practical
practical not required
Assessment criteria – Knowledge
The learner can: 6.1 explain the meaning and need for modulation 6.2 define **types of modulation** 6.3 identify **modulation method** from waveform diagrams 6.4 describe am waveforms for **different types of modulating signal**. 6.5 describe **modulation** index 6.6 explain how amplitude modulation of an R.F. carrier wave by a sinusoidal tone produces a complex wave having a number of **frequency components** 6.7 describe the effect of a modulation index greater than 1 6.8 describe components of double-sideband and single sideband am signals 6.9 describe benefits of single-sideband systems 6.10 explain the bandwidth required for a double-sideband amplitude modulated signal 6.11 explain the process of demodulation of an amplitude modulated signal 6.12 describe **terms** used in FM systems 6.13 explain how the bandwidth required for an FM service is determined 6.14 explain why FM radio services operate at very high frequency (V.H.F.) and above. 6.15 describe the frequency/amplitude characteristic of a discriminator suitable for demodulating an FM signal.

Range
Types of modulation Amplitude Modulation(AM), Frequency Modulation(FM), Phase Modulation (PM) **Modulation method** Amplitude Modulation (AM), Frequency Modulation (FM). **Different types of modulating signal** **S**ine-wave, audio (voice) signal **Frequency components** fc, fc – fm and fc + fm; An amplitude modulated carrier can be given by the equation: $V_{mod} = V_{unmod} [1 + m \cos(\omega_m t)] \times \cos(\omega_c t)$; where $\omega_m = 2\pi f_m$ and $\omega_c = 2\pi f_c$ and m= modulating index expanded gives; $V_{mod} = V_{unmod} [\cos(2\pi f_c t) + (m/2)\cos(2\pi\{f_c+f_m\}t) + (m/2)\cos(2\pi\{f_c-f_m\}t)]$ **Terms** Frequency deviation, maximum deviation, deviation ratio

Guidance
6.4 Learners can use sketch diagrams to describe modulation index 6.5 Learners should be able to sketch an amplitude modulated waveform indicating the frequency components fc, fc – fm and fc + fm. 6.7 Learners should be able to use a frequency spectrum diagram to describe the components of double-sideband and single sideband AM signals 6.10 Demodulation can be expressed using Block diagrams showing the stages of demodulation and the waveforms at each stage. 6.15 If learners use diagrams, working limits should be indicated.

Unit 302 Communication systems and digital networks 2

Level:	3
GLH:	111
Aim:	This unit covers areas including the fundamentals of data communication, the OSI reference model and transmission protocols.

Learning outcome
1. data communication fundamentals
Assessment criteria – Practical
The learner can: 1.1 draw block diagrams for two - way communication systems between computers over a standard public telephone network. 1.2 configure parameters for new communications connections using terminal emulation software 1.3 calculate character transmission rates
Assessment criteria – Knowledge
The learner can: 1.4 identify **components** of a simple communication system 1.5 describe different **media** used in data communication 1.6 describe main **benefits** of data networking 1.7 explain the difference between digital and analogue signals 1.8 define **digital data communication terms** 1.9 explain data **transmission methods** 1.10 describe digital transmission **data formats** and state the benefits and drawbacks of each 1.11 explain the difference between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) 1.12 list **examples of DTE and DCE equipment** 1.13 describe serial **transmission formats** 1.14 describe packet switched **network methods**, and compare the benefits and drawbacks of each. 1.15 describe data **switching methods**, and compare the benefits and drawbacks of each 1.16 explain the meaning of the term 'protocol' in the context of data communication. 1.17 describe **data coding methods** 1.18 define **data communication terms** 1.19 describe error **correction methods**

Range
Parameters Name, port, bits per second (bps), data bits, parity, stop bit, flow control. **Components** Source, transmitter, transmission system, receiver, destination **Media** Copper cable, fibre optical cable, radio waves, infrared. **Benefits** Data sharing, hardware sharing, data security and management, connectivity and communication. **Digital data communication terms** Bits, bytes **Transmission methods** Simplex, half-duplex, full-duplex **Data formats** Serial, parallel **Examples of DTE and DCE equipment** DTE Computer, DCE Modem **Transmission Formats** Synchronous, asynchronous **Network Methods** Connectionless, connection-oriented **Switching Methods** Circuit, message, packet, fast packet. **Data coding methods** Source, channel, line. **Data communication terms** Data, information, redundancy. **Error correction Methods** Automatic Repeat Request (ARQ), Forward Error Control (FEC).

Learning outcome
2. the open systems interconnection (OSI) reference model
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 2.1 identify international standards organisations (ISO) reasons for the development of the OSI seven layer reference model 2.2 explain the operation of the OSI 2.3 identify the OSI layer structure and numbering 2.4 describe the function of the **layers** of the OSI 2.5 explain the peer-to-peer communication concept of the OSI layers between adjacent systems 2.6 explain the meaning of the **terms** used within the OSI model. 2.7 explain reasons why all of the **OSI layers** do not have to be

represented in every LAN **implementation**.

Range
OSI Layers Physical, Data link, Network, Transport, Session, Presentation, Application. **Terms** Encapsulation, segmentation, fragmentation. **Implementation** NetBEU

Learning outcome
3. transmission control protocol / internet protocol (TCP/IP)
Assessment criteria – Practical
The learner can: 3.1 interconnect computers using a hub or crossover cables 3.2 record IP addresses and subnet mask for interconnected computers 3.3 use the 'ping' command to establish connectivity 3.4 change IP addresses and subnet masks 3.5 assess the effects of computers configured for different networks
Assessment criteria – Knowledge
The learner can: 3.6 identify reasons for the use of protocols in data communication 3.7 identify the TCP/IP (transmission control protocol / internet protocol) suite of protocols 3.8 describe features of the TCP/IP protocol, referencing the department of defence (DOD) protocol model 3.9 compare the TCP/IP protocol with the open systems interconnect (OSI) model 3.10 describe the function of each of the **TCP/IP layers** 3.11 explain the **function** and **operation** of the TCP protocol 3.12 explain the **function** and **operation** of the IP protocol 3.13 identify the layer of the OSI model at which the IP protocol operates 3.14 explain the function of a protocol for each layer of the TCP/IP protocol suite 3.15 describe the structure of the IP datagram header for version 4 (ipv4)and 6 (ipv6) 3.16 describe the purpose of each field of the IP datagram for version 4 (ipv4) and 6 (ipv6) 3.17 state the number and function of **TCP ports** 3.18 state the number and function of the **user datagram protocol (UDP) ports** 3.19 explain the base 2 and base 10 numbering systems 3.20 convert from one numbering system to the other using binary and dotted decimal notation of IP addresses 3.21 explain the classful internet addressing scheme and identify the **classes**

3.22 identify the default subnet masks for classes a, b, and c 3.23 explain the drawback of the classful internet addressing scheme 3.24 explain classless inter-domain routing (CIDR) 3.25 list methods of expressing ipv6 addresses and describe their **types** 3.26 explain why there is a need for subnetting and how it is implemented 3.27 identify broadcast addresses within a subnetted network-addressing scheme 3.28 identify the network and host portions of a given IP address 3.29 calculate subnet addresses for subnetted ip addressing schemes 3.30 list host ranges for subnetted IP addressing schemes 3.31 explain reasons for the allocation of **reserved IP addresses**. 3.32 state who is responsible for allocating ip addresses for use on the internet. 3.33 explain the purpose and use of TCP/IP **services** 3.34 explain the role of routers within interconnected IP networks.

Range
TCP/IP Layers Application layer, transport layer, Internet layer, network access layer **TCP Function** Data recovery, flow control, guaranteed delivery. **TCP Operation** Three-way handshake, port allocation, data segmentation. **IP Function** Addressing, routing / indirect delivery **IP Operation** Data encapsulation and formatting/packaging, fragmentation and reassembly, **TCP Ports** 21-File Transfer Protocol (FTP), 23-Telnet, 25-Simple Mail Transfer Protocol (SMTP), 80-Hypertext Transfer Protocol (HTTP). **UDP Ports** 53-Domain Name Service (DNS), 69-Trivial File Transfer Protocol (TFTP). **Classes** A, B, C, D, E **Methods** Full, shorthand, mixed notation **Types** Unicast, multicast, anycast **Reserved IP addresses** Loopback, unassigned, private **Services** Dynamic Host Configuration Protocol (DHCP), Domain Name Service (DNS).

Learning outcome
4. data packets, frames and cells
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 4.1 explain **terminology** used within data transmission. 4.2 explain media channel capacity including the nyquist sampling theorem and the shannon capacity formula 4.3 explain transmission **impairments** and how they can be overcome 4.4 explain the purpose of standards and standards bodies in data communication 4.5 explain data encoding 4.6 describe examples of **data encoding schemes** 4.7 identify **standards** for data communication interfaces. 4.8 identify **data link layer protocols** 4.9 describe data link **flow control methods**. 4.10 explain the meaning of error detection and control in data transmission 4.11 describe examples of **error-detection** schemes. 4.12 describe characteristics of the **HDLC protocol** 4.13 describe the frame **structure** of the frame relay protocol 4.14 describe the operation and facilities offered by the frame relay protocol 4.15 describe **factors** which make the frame relay protocol capable of higher bit rates than the standard HDLC protocol. 4.16 describe the **operation** and **facilities** provided by the x.25 packet switching protocol. 4.17 describe the **construction**, operation and **facilities** offered by the asynchronous transfer mode (ATM) protocol. 4.18 describe the **ieee 802.3 frame** format and explain the function of each field.

Range
Terminology Protocols, frames, packets, cells, guided media, unguided media, point-to-point, bandwidth, data **Impairments** Attenuation, delay distortion, noise **Data encoding schemes** Pulse Code Modulation (PCM), Frequency-Shift Keying (FSK), Manchester encoding. **Standards** V.24/EIA-232-F, EIA-423 / RS-423, EIA-422 (CCITT V.11) / RS-422, X.21 **Data link layer protocols** High-Level Data Link Control (HDLC), Logical Link Control (LLC), **Point-to-Point Protocol** (PPP), **Link Access Procedure** (LAP).

Flow control methods

Stop-and-wait, sliding-window.

Error-detection

Parity check, Cyclic Redundancy Check (CRC), Hamming, repetition codes, checksums.

HDLC protocol

Frame structure and operation

Structure

Format and size

Factors

Reduced error checking, recovery in higher-level protocols, minimum flow control.

X.25 packet switching protocol Operation

Link Access Procedure Balanced (LAPB), incoming and both-way, set-up and clear down, Switched Virtual Circuit (SVC) and Permanent Virtual Circuit (PVC)

X.25 packet switching protocol Facilities

Routing by Network User Address (NUA), error checking, cyclic count, Packet Assembler/Disassembler (PAD), fault logging.

ATM Construction

Format, size, Virtual Path Identifier (VPI), Virtual Channel Identifier (VCI).

ATM Facilities

Quality of Service (QoS), supports both voice and data communications.

IEEE 802.3 frame

Preamble, Start Frame Delimiter (SFD), Destination Address (DA), Source Address (SA), length type, LLC data, pad, Frame Check Sequence (FCS)

Learning outcome
5. switching and routing
Assessment criteria – Practical
The learner can: 5.1 identify and label network devices correctly 5.2 record the layer in which network devices operate 5.3 identify collision and broadcast domains 5.4 create and record a classfull IP addressing scheme 5.5 determine appropriate protocols 5.6 create a router configuration file for a router
Assessment criteria – Knowledge
The learner can: 5.7 explain the **functions** of layer 2 switches 5.8 describe the different **layer 2 switching methods** 5.9 describe the spanning tree algorithm (sta) and its **application** in switched networks 5.10 explain **benefits** of using **virtual local area networks (VLANs)** 5.11 state the device used to interconnect VLANs 5.12 state the meaning of **trunking** 5.13 identify examples of trunking **standards** and **protocols** 5.14 describe the function of a router in a network

5.15 explain the meaning of **routing** and **routed protocols** and identify examples of each

5.16 describe **connectors** and **interfaces** used for connecting routers to a network

5.17 describe **networking equipment features** offered by competing manufacturers

5.18 explain the use of character based American symbolic code for information interchange (ASCII) terminal or **terminal emulation software** for the configuration of a router

5.19 describe the use of **commands** to create a configuration file for a given router

5.20 explain the difference between a **non-routable protocol** and a **routable protocol** and give examples of both

5.21 explain **subnetting** and state the **benefits** of its use

5.22 explain transmission control protocol/internet protocol (TCP/IP) routing methods

5.23 identify where TCP/IP routing methods would be used and state their benefits and drawbacks

5.24 describe **routing metrics** in the context of routing protocols

5.25 describe **methods** used by distance vector routing protocols

5.26 identify **examples** of distance vector routing protocols

5.27 describe **methods** used by link-state routing protocols

5.28 identify **examples** of link-state protocols

5.29 explain the **purpose** of network traffic filtering

5.30 list **parameters** that can determine network traffic filtering.

Range
Functions
Creates collision domains, full duplex data transfer capability, Virtual Local Area
Network (VLAN) creation
Layer 2 switching methods
Cut through, store-and-forward, fragment free
Application
Spanning Tree Protocol (STP)
VLAN Benefits
Simplifying moves and changes, formation of virtual workgroups.
Trunking
Multi channel inter-switch connections
Trunking Standards
Institute of Electronic and Electrical Engineers (IEEE) 802.1q
Trunking Protocols
VLAN Trunking Protocol (VTP)
Examples of Routing protocols
-IGRP, RIP, IS-IS
Examples of Routed protocols
IP, IPX
Connectors
EIA/TIA-232, EIA/TIA-449, V.35, X.21, EIA-530, RJ45
Interfaces

Serial, Ethernet, token ring, Integrated Services Digital Network (ISDN).

Networking equipment Features

Packet forwarding rate in packets per second (pps), variety of interfaces, mean-time- between-failures (mtbf)

Terminal emulation Software

Hyperterminal, Teraterm Pro

Commands

Interface, Internet Protocol (IP) addresses, routing protocols, encapsulation, clock rate, interface status, device name.

Non-routable protocol

NetBEUI/NetBIOS, Data Link Control (DLC), Local Area Transport (LAT)

Routable protocol

IP, Internet Packet eXchange (IPX)

Subnetting Benefits

Logical segmentation of networks, localisation of network traffic

Routing metrics

Best path, shortest path, hop count, bandwidth, delay

Routing Methods

Static, dynamic

Distance vector routing protocol methods

Hop count, distance

Vector routing protocol Examples

RIP, Interior Gateway Protocols (IGRP)

Link-state routing protocol methods

Bandwidth, delay, traffic loading

Link-state protocols Examples

Open Shortest Path First (OSPF), **Intermediate System to Intermediate System** (IS-IS)

Network traffic Parameters

Transmission Control Protocol (TCP)/ User Datagram Protocol (UDP),port number, application, source/destination addresses, IPX, Service Advertisement Protocol (SAP) number

Unit 303 Fundamentals of electronic communication 3

Level:	3
GLH:	114
Aim:	This unit covers areas including power supply systems, optical fibre systems, modulation & modems and digital transmission and multiplexing.

Learning outcome
1. power supply systems
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 1.1 state **definitions** associated with direct current (D.C.) power supplies 1.2 perform calculations for **definitions** associated with D.C. power supplies 1.3 describe **stages** required to form a complete series stabiliser 1.4 explain the operation of a simple series regulator circuit using **appropriate electronic components** 1.5 describe **methods of protection** used for D.C. power supplies 1.6 describe the technique for making the output voltage of a stabilised power supply continuously variable down to approximately zero volts 1.7 describe **methods** for achieving an alternating current (A.C.) supply 1.8 explain the use of an uninterruptable power supply (ups) 1.9 explain the functions of the **essential stages** of an ups

Range
Definitions Open-circuit output voltage, short-circuit output current, regulation, output resistance **Stages** Voltage reference, comparator, d.c. amplifier, pre-regulator **Appropriate electronic components** Power transistor as emitter follower, zener diode, resistors **Methods of protection** Over-voltage, current limiting, fuses

Methods
Battery–d.c. motor–a.c. generator, switching device–transformer
Essential stages
Rectifier, battery bank, inverter, filter

Guidance
1.3 Learners can use block diagrams to describe stages
1.4 Learners can use circuit diagrams to explain operation

Learning outcome
2. optical fibre systems
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 2.1 describe **materials** and **structure** of optical fibres. 2.2 explain the basic operation of an optical fibre **communication link** 2.3 explain **advantages** and **disadvantages** of optical fibre compared to copper transmission lines. 2.4 explain **terms** associated with optical fibres 2.5 state **snell's law** 2.6 derive the **critical angle** using snell's law for an optical fibre. 2.7 perform calculations using snell's law, the critical angle and the associated terms 2.8 explain **power losses** in optical fibres 2.9 explain the cause and effect of dispersion in optical fibres 2.10 describe the structure and typical dimensions of optical fibre **modes** 2.11 describe the **methods** for joining and terminating optical fibres 2.12 explain the most commonly used **wavelengths** for optical fibres systems 2.13 compare the basic **transmission properties** of LEDs (light emitting diodes) and SLDs (semi-conductor laser diodes) 2.14 compare the basic **reception properties** of pin diodes and APDs (avalanche photo diodes) 2.15 state **safe working practices** when working with optical fibres and SLDs.

Range
Components Signal source, optical transmitter, fibre, optical receiver, signal sink **Classifications** Single-mode, stepped-index, graded-index **Transmitting devices** Light Emitting Diodes (LEDs), Semiconductor Laser Diodes (SLDs) **Receiving devices** PIN diodes, Avalanche Photo Diodes (APDs) **Materials** Glass–glass, glass–plastic, plastic–plastic **Structure** Core, cladding, jacket **Communication link** Signal source, optical transmitter, fibre cable, optical receiver, signal destination **Advantages** Bandwidth, immunity to crosstalk, immunity to static interference, environmental immunity, durability, reliability, security, lower losses **Disadvantages** Interfacing costs, strength, no remote electrical power facility, susceptible to bending losses, specialised tools and training required **Terms** Reflection, refraction, refractive index, acceptance angle, critical angle, total internal reflection, numerical aperture, acceptance cone **Snell's law** $n_1 \sin\theta_1 = n_2 \sin\theta_2$ where n_1 is the refractive index of the core, n_2 is the refractive index of the cladding, θ_1 is the angle of incidence, θ_2 is the angle of refraction, **Critical angle** Critical angle $\theta_c = \sin^{-1}(n_2/n_1)$ when $\theta_2 = 90^\circ$ **Power losses** Absorption, Rayleigh (scattering), radiation (microbend) **Modes** Stepped-index, graded-index, single mode, multimode **Methods** Arc fusion splicing, mechanical splicing **Wavelengths** 850nm, 1300nm, 1550nm **Transmitter properties** Cost, bandwidth, power **Receiver properties** Conversion efficiency, transit time, spectral response **Safe working practices** Cleanliness, eye protection, correct disposal of glass fragments

Guidance
2.12 Learners can use diagrams to justify wavelengths

Learning outcome
3. modulation and modems
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 3.1 explain **reasons** why unidirectional pulse data cannot be transmitted directly over a standard analogue telephone network 3.2 explain how digital data is represented by different **parameters** in different **modulation systems** 3.3 describe how **groups** of binary digits are employed in data communication 3.4 describe the function and **forms** of the parity digit 3.5 explain **modulation techniques** suitable for the transmission of digital data 3.6 explain **benefits** of transmitting only the first pair of side frequencies in FSK (frequency shift keying) and PSK (phase shift keying) 3.7 describe **functions of a modem** 3.8 explain **distinctions** between synchronous and asynchronous working 3.9 compare **advantages** of **synchronous** and **asynchronous working** 3.10 describe **causes** of errors in a received data signal. 3.11 explain **advantages** of FSK and PSK over ask (amplitude shift keying) for data transmission 3.12 describe the function of **stages** required to use the public switched telephone network (PSTN) for the transmission and reception of digital data 3.13 describe **units** of a typical modem 3.14 describe **modulation methods** used with practical modems 3.15 explain the requirement for asymmetrical working in duplex modems 3.16 state the reason for trellis coding in modems 3.17 describe the function of cable modems 3.18 explain the differences between cable modems and modems designed for use over the PSTN 3.19 describe dedicated data networks and the **benefits** of using them

Range
Reasons Absence of d.c. circuit, distortion **Parameters** Amplitude, frequency, phase **Modulation schemes** Frequency Shift Keying, (FSK), Phase Shift keying (PSK), Quadrature Amplitude Modulation (QAM), Quadrature Phase Shift Keying, (QPSK), Differential Phase Shift Keying (DPSK) **Modulation systems** Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM), QAM **Groups** Dibits, tribits **Forms** Odd, even **Modulation Techniques** FSK, PSK, QAM, QPSK, DPSK **Benefits – FSK & PSK transmission** Bandwidth reduction, power efficiency **Functions of a modem** Modulation, demodulation **Distinctions** Synchronisation, speed, overheads **Advantages of synchronous and asynchronous working** Synchronised clocks, speed, overheads **Causes** Noise, bandwidth, bit rate **Advantages** Noise reduction, increased bit rate **Stages** Data source, dial-up modem, exchanges, dial-up modem, data destination **Units** Filter, amplifiers, equaliser, scrambler/descrambler. encoder/decoder, modulator/demodulator, clock, clock recovery **Modulation methods** DPSK, QPSK, QAM, QPSK, DPSK **Difference** No analogue–digital–analogue conversions **Benefits - dedicated data networks** Noise reduction, faster bit rate, elimination of the need for modems

Guidance
3.2, 3.3, 3.12 and 3.13 learners can use diagrams to demonstrate their understanding.

Learning outcome
4. digital transmission and multiplexing
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 4.1 describe how noise appears on different types of signal 4.2 explain **reasons** for noise being cumulative throughout the length of an analogue communication system 4.3 describe means by which the effect of noise is reduced and made non-cumulative on a digital system 4.4 define bit rate 4.5 explain the relationship between bit rate, system bandwidth and signal-to-noise ratio as expressed by the **hartley-shannon law** 4.6 perform calculations using the **hartley-shannon law** 4.7 describe the **conditions** that provide a high bit rate using pulse regeneration 4.8 define the term 'multiplexing' 4.9 differentiate between **multiplexing methods** 4.10 explain the need for multiplexing 4.11 explain the connection between multiplexing and modulation 4.12 explain **factors** that make demultiplexing more difficult than multiplexing 4.13 explain the **concept** of space division multiplexing (SDM). 4.14 describe **channel sharing** in frequency division multiplexing (FDM) 4.15 explain the reason for channel separation in FDM. 4.16 explain the mechanism of channel separation in FDM. 4.17 describe the essential **features** of TDM. 4.18 define the **terms** used in TDM. 4.19 explain the **benefits** of digital time division multiplexing (TDM) systems. 4.20 describe the **relationship** between sampling rate, channel time slot and the possible number of channels. 4.21 perform calculations using the relationship between sampling rate, channel time slot and the possible number of channels. 4.22 explain **elements** of statistical time division multiplexing (TDM) 4.23 describe code division multiplexing (CDM) in terms of its **essential elements** 4.24 explain **multiple access techniques**.

Range
Communication links Analogue, digital **Multiplexing methods** Space Division Multiplexing (SDM), Frequency Division Multiplexing (FDM), Time Division Multiplexing (TDM), Code Division Multiplexing (CDM) **Signal** Analogue, rectangular pulses **Reasons** Thermal noise proportional to resistance, resistance proportional to length **Hartley-Shannon law** $I = B\log_2(1+S/N)$ where *I* is the information capacity in bits/s, *B* is the bandwidth in Hertz, *S/N* is the signal-to-noise power ratio **Conditions** Wide bandwidth, low signal-noise ratio **Types** SDM, FDM, TDM, CDM **Factors** Synchronisation, filtering **Concept** Circuits spaced apart, one channel per circuit **Channel sharing** Each channel permanently allocated a part of the total frequency band **Benefits** Noise reduction, cable plant utilisation costs **Features** Common highway, channel interleaving, synchronisation **Terms** Channel, time slot, guard time, sampling rate **Relationship** $n \times f \times T_S = 1$ where *n* is the number of channels, f is the sampling rate and T_S is the period of a time slot **Elements** Dynamic slot allocation, overheads, data throughput, bit rate **Essential elements** Spreading code, chip rate, data rate, synchronisation **Multiple access Techniques** Frequency Division Multiple Access (FDMA), Time Division Multiple Acess (TDMA), Code Division Multiple Access (CDMA)

Guidance
4.3 Learners can use sketches to demonstrate their understanding. 4.18 Learners can use diagrams to demonstrate their understanding.

Learning outcome
5. pulse modulation and time division multiplexing (TDM)
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 5.1 describe principles of the different **methods of pulse modulation** 5.2 describe **pulse parameters** of a pulse amplitude modulated (pam) signal in relation to the information content 5.3 describe the basic method of the production of pam 5.4 explain the **relationship** between the frequencies in an analogue signal and the amplitude samples for accurate representation and reconstruction 5.5 perform calculations for the construction and reconstruction of an analogue single from amplitude samples 5.6 explain **problems** caused when the sampling conditions are not met 5.7 describe the frequency spectrum of a pam signal, identifying **important frequencies** 5.8 explain the means of recovery for the baseband signal in pam 5.9 explain **shortcomings** of a pam/TDM transmission system. 5.10 explain the meaning of quantisation in PCM. 5.11 explain the **relationship** between the number of information bits and the number of quantisation levels 5.12 explain the reason for quantisation in PCM systems 5.13 describe quantisation noise and the **factors** that determine its level 5.14 explain the **benefits of non-linear quantisation** 5.15 describe the correspondence between **parameters in PCM** 5.16 describe the principle of encoding and decoding speech in PCM with reference to essential units 5.17 calculate bandwidth requirements for PCM systems given **relevant parameters** 5.18 explain **benefits of PCM** transmission systems 5.19 define **terms** used in the timing structure of a PCM system 5.20 describe the timing structure for a 30-channel PCM system identifying the use of the **time slots** 5.21 explain the benefit of the multiframe structure of the PCM system. 5.22 describe the structure of **digital hierarchies** 5.23 identify **major units** of a 30-channel PCM multiplexer and demultiplexer system. 5.24 describe the function of **major units** for a 30-channel PCM multiplexer and demultiplexer system 5.25 describe **main units** of a PCM regenerator

Range
Types Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), Pulse Position Modulation (PPM), Delta modulation (DM) **Techniques** Frequency Division Multiplexing (FDM), Time Division Multiplexing (TDM) **Methods of pulse modulation** PAM, PWM, PPM, DM **Pulse parameters** Amplitude, width, position **Relationship** Amplitude sampling rate must be greater than twice the highest analogue frequency **Reconstruction requirement** Amplitude samples must be taken at more than two equally spaced intervals per cycle. **Problems** Accurate information recovery, aliasing **Important frequencies** Baseband frequencies, sampling frequency, sidebands, harmonics, bandwidth **Shortcomings** Cumulative noise, bandwidth **Relationship** $n = 2^q$ where n is the number of information bits, q is the number of quantisation levels **Factors** Dynamic range, number of quantisation levels **Parameters in PCM** Number of quantisation levels, quantisation noise, bandwidth **Benefits of non-linear quantisation** Greater accuracy, improved signal-to-noise **Units** Filters, PAM modulator/demodulator, Analogue-digital/digital-analogue converters, Parallel-series/series-parallel converters **Relevant parameters** Baseband, sampling rate, number of quantisation levels, number of multiplexed channels **Benefits of PCM** Independence of transmission quality and distance, increased call-carrying capacity for an existing cable network, utilisation of same transmission path for difference services (audio, video and data), effective use pf transmission paths having low signal-to-noise **Terms** Time slot, frame, multiframe **Time slots** Time slot 0, time slot 16, time slots 1-15, time slots 17-31 in odd and even frames **Digital hierarchies** Plesiochronous Digital Hierarchy (PDH), Synchronous Digital Hierarchy (SDH)

Major units

Channel sampling gates, Encoder/decoder, combiner/decombiner, line coder/line decoder, transmit timing/timing extraction

Main Units

Reshaping, retiming, timing extraction

Guidance

5.1 Learners can use wave form diagrams to show their understanding.

5.3 Learners can use a simple **circuit** and sketched waveform diagrams to show their understanding.

5.7 Learners can use sketches and numerical values to show their understanding.

5.10, 5.13, 5.16, 5.20, 5.22 and 5.23 Learners can use diagrams to show their understanding

5.25 Learners can use diagrams along with typical voltage waveforms to illustrate the regeneration process.

Learning outcome

6. access network and digital telephone exchanges

Assessment criteria – Practical

The learner can:

practical not required

Assessment criteria – Knowledge

The learner can:

6.1 describe functions of the **circuit elements** of a telephone

6.2 explain the term 'sidetone' and identify the circuit component that ensures its correct level

6.3 explain **benefits** of central battery working

6.4 explain the need for switching in telecommunication networks using the **standard formula**

6.5 describe **factors** that show that the public switched telephone network (PSTN) is an example of a circuit-switched network

6.6 describe how **signals** are detected by a telephone or exchange equipment in electronic exchange systems

6.7 explain **numbering schemes** used for telephone calls.

6.8 describe value added exchange **services**

6.9 explain the expression 'telephone traffic' and its effect on switching

6.10 describe telephone traffic variation over a 24 hour period

6.11 define the term 'Erlang'

6.12 state the **traffic intensity formula**

6.13 describe **terms** associated with telephone traffic

6.14 state **definitions** for grades of service

6.15 explain the connection between the Erlang and probability

6.16 perform calculations involving

- Erlang
- traffic intensity
- traffic offered
- traffic lost

- Busy Hour

6.17 describe **related factors** that affect the required level of plant

6.18 perform calculations involving

- congestion probabilities
- traffic intensity
- the amount of plant

6.19 explain the factor that determines the number of cross points in a matrix above a particular traffic level

6.20 explain that the control of calls can be achieved by an automatic computer system

6.21 explain the extent to which SPC equipment is associated with calls

6.22 describe **main elements of SPC**

6.23 explain the action of SPC equipment in setting up an own-exchange call

6.24 describe physical **components** of an access network

6.25 list the transmission **constraints and liabilities** associated with copper twisted wire cables

6.26 describe the basic operation of **technologies** utilised in an access network to provide digital transmission capability

6.27 describe **operations** involved in setting up a connection across a digital exchange using time-space-time switching

6.28 describe **main services** offered by digital exchanges and digital private automatic branch exchanges (PABXs)

Range

Necessary elements

Transmitter, receiver, battery, induction coil, cradle switch, calling generator, alerting bell

Voice switching technologies

Electromechanical two-motion (Strowger) , crossbar, electronic, digital

Types of call

Local, national, international

Hierarchy

International gateway (class 1 office), national tandem (class 2 office), regional tandem (class 3 office), local tandem (class 4 office), local exchange (class 5 office)

Systems

Digital Switching Subsystem (DSS), Management Statistics Subsystem (MSS), Digital Subscriber Switching Subsystem (DSSS), Maintenance Control Subsystem (MCS), Processor Utility Subsystem(PUS), Test Network Subsystem (YNS), Call Processing Subsystem (CPS), Message Transmission Subsystem (MTS), Network Synchronisation Subsystem (NSS), Automatic Announcement Subsystem (AAS)

Circuit elements

Microphone, receiver, induction coil, regulator, bell, switches

Benefits

Cost, consistency,

Standard formula

$l = 0 \cdot 5n(n-1)$ where *l* is the number of links required to connect *n* users

Factors

Establishment of physical circuit before communication commences, circuit maintained throughout period of communication

Signals

Calling signal, dial pulses, keypad pulses, multifrequency keypad signals, ringing, called subscriber answer, cleardown

Numbering schemes

Local, national, international

Services

Call diversion, call waiting, ring back, call barring, hold call, three-way calling, caller display, etc.

Types of exchange

Local, national, international

Traffic intensity formula

$A = c.t / T$ where *A* is the traffic intensity in Erlangs, *c* is the number of calls, *t* is the average duration of a call, *T* is the period of measurement

Terms

Traffic offered, traffic carried, traffic lost, busy hour

Two definitions

Ratio of traffic lost to traffic offered, probability of blocking

Related factors

Congestion probabilities, traffic level, busy hour

Main elements of SPC

Scanners, processors, memory, maintenance, storage, signal distribution

Components

Copper twisted wire cables, poles, primary and secondary connection points, joint boxes, cable ducting, Main Distribution Frame (MDF), leased lines

Constraints and liabilities

Ingress of moisture, size, attenuation, bandwidth, susceptibility to faults

Technologies

Integrated Services Digital Network (ISDN), Asymmetric Digital Subscriber Line (ADSL), modem

Operations

Digital Line Termination (DLT), Time Switch (TSW), multiplexing, Cross Office Slot (XOS), receiv and transmit stores, Space Switch (SSW))

Main Services

Call diversion, call waiting, ring back, call barring, hold call, three-way calling, extension status, night service, executive intrusion, route optimisation, forced release, statistics, co-located PABX and/or centres

Guidance

6.10 Learners can use diagrams to demonstrate their understanding.

6.22 and 6.23 Learners can use Erlang B representation curves to demonstrate their understanding.

6.26 and 6.27 Learners can use diagrams to demonstrate their understanding.

Unit 304 Communication systems and digital networks 3

Level:	3
GLH:	105
Aim:	This unit covers areas including structured cabling, the different types of area networking, transmission systems, end systems and network management.

Learning outcome
1. structured cabling
Assessment criteria – Practical
The learner can: 1.1 demonstrate cabling designs compliant with international standards organisation/international electrotechnical commission (ISO/IEC) 11801 1.2 interpret link test results and compare with the relevant worst-case performance specifications 1.3 design a standard's based cabling solution based on a building plan 1.4 source information on cabling standards 1.5 make up and test network cables, fitting suitable connectors
Assessment criteria – Knowledge
The learner can: 1.6 explain the meaning of the term 'structured cabling' when applied to cabling for data communication in commercial premises 1.7 explain the purpose and **reasons** for the cabling standard ISO/IEC 11801 1.8 describe the function of **elements** that make up the generic cabling system and the associated **terminology** 1.9 describe different **media types** referenced in the ISO/IEC 11801standard 1.10 explain why building pathways involving high temperatures require different types of cable 1.11 explain cable **performance terminology**. 1.12 describe installation practices stipulated by the ISO/IEC 11801standard 1.13 define link performance using **categories** and their **classes** 1.14 explain the importance of conformance testing in accordance with standard ISO/IEC 14763-3 and 61935-1 1.15 explain **parameters** that are tested in link performance tests 1.16 explain the importance of correctly documenting the installed network in accordance with the guidelines outlined in the ISO/IEC 14763-1 standard.

Range
Reasons Voice/data applications support-now and future, multiproduct, multivendor, ease of moves and changes, generic. **Elements** Campus, building, horizontal cabling, telecommunications outlet, telecommunications closet and equipment room **Terminology** Floor Distributor (FD), Building Distributor (BD), Campus Distributor (CD), Telecommunication Outlet (TO), Transition Point (TP) **Media types** 4-pair (or 2-pair) 100 Ω (or 120 Ω) balanced cable, 2-pair 150 Ω Shielded Twisted Pair (STP), 62.5/125 µm (or 50/125 µm) optical fibre, 6/125 µm (or 10 /125µm) optical fibre, wireless, infrared **Performance Terminology** Bandwidth, propagation delay, delay skew, attenuation, Attenuation-to-Crosstalk Ratio (ACR) **Categories** 3, 5, 5e, 6 **Classes** A, B, C, D, E, F **Parameters** Near End Crosstalk (NEXT), Far End Crosstalk (FEXT), Equal Level Far End Crosstalk (ELFEXT), Power Sum NEXT (PSNEXT), return loss

Guidance
1.1 Learners can use diagrams to demonstrate understanding.

Learning outcome
2. local area networks (LANs), metropolitan area networks (mans) and wide area networks (wans)
Assessment criteria – Practical
The learner can: 2.1 source information on network **equipment** products. 2.2 use a **network simulator** to investigate LAN activity 2.3 construct a LAN and establish a link using WAN technology. 2.4 calculate bandwidth requirements for LAN designs 2.5 implement backup procedures. 2.6 implement changes to a small LAN.
Assessment criteria – Knowledge
The learner can: 2.7 define the terms LAN, MAN and WAN. 2.8 explain the difference between broadcast-media-access and non-broadcast-media-access technologies 2.9 state shared media LAN **technologies** and their operating speeds. 2.10 describe how ethernet and token ring technologies work 2.11 describe LAN **topologies**. 2.12 describe the role of **equipment** in a LAN. 2.13 identify the layer within the ISO OSI model that each item of LAN **equipment** operates 2.15 explain the **causes** and **effects** of congestion on a network. 2.16 list **factors** that will reduce the total throughput of data within a LAN or reduce the bandwidth available for each individual node. 2.17 identify **transmission media** deployed in LANs. 2.18 state **typical areas** covered by LANs. 2.19 state **typical areas** covered by MANs. 2.20 state **typical areas** covered by WANs. 2.21 identify **technologies** used to implement a MAN and WAN. 2.22 list **examples of WANs** 2.23 explain the Institute of Electrical and Electronic Engineers (IEEE) 802 **standards** for LAN access control

Range
Technologies Ethernet, token ring, Fibre Distributed Data Interface (FDDI), fast Ethernet, gigabit **Topologies** Bus, tree, ring and star extended star **Network simulator** Cnet, Opnet **Activity** Traffic flow, protocol comparison, troubleshoot **Equipment** Hubs, switches, routers and Network Interface Cards (NICs) **Causes** Increased traffic, high demand for access **Effects** Increased collisions, slow response, time-outs **Factors** Ethernet collisions, high volume of users, broadcast storms, inadequate physical segmentation, increased traffic, data backup procedures, faulty cabling, Electromagnetic Interference (EMI) **Transmission Media** Shielded Twisted Pair (STP), Unshielded Twisted Pair (UTP), coaxial cable, optical fibre, wireless, infrared **Typical LAN areas** A company site, a home, an office **Typical MAN areas** University campus, local government offices **Typical WAN areas** A company operating networked offices in Kenya and Sri Lanka, an international company with offices in several countries. **MAN Technologies** Line-of-sight microwave, Synchronous Digital Hierarchy (SDH), leased line **WAN Technologies** Frame Relay, Asynchronous Transfer Mode (ATM), X.25 packet-switched WAN technologies **Examples of WANs** A company operating networked offices in Kenya and Sri Lanka, an international company with offices in several countries. **IEEE Standards** 802.3 Carrier Sensing Multiple Access/ Collision Detection (CSMA/CD), Medium Access Control (MAC)

Learning outcome
3. transmission systems
Assessment criteria – Practical
The learner can: 3.1 investigate the use of dense wavelength division multiplexing (DWDM) techniques. 3.2 source information on itu-t standards on synchronous digital hierarchies (SDH) and American national standards institute (ANSI) synchronous optical network (SONET) standards 3.3 describe the stm1 frame structures, indicating row and column sizes and total frame duration. 3.4 perform **calculations** on stm1 frame structures
Assessment criteria – Knowledge
The learner can: 3.5 describe **benefits** and **drawbacks** of using optical fibres. 3.6 explain the concept of using wavelength division multiplexing (WDM). 3.7 explain the basic operating principles of **time division multiplexing systems**. 3.8 explain **data transmission multiplexing systems** 3.9 explain plesiochronous digital hierarchy (PDH) (itu-t g.702) systems and highlight their drawbacks. 3.10 explain the structure and operation of **digital carrier systems**. 3.11 describe types of **traffic** that can be transported over SONET/SDH. 3.12 describe the function of an add/drop multiplexer (ADM). 3.13 describe the function of virtual containers (VCS) in the SDH multiplex system. 3.14 describe how **PDH traffic classes** can be transported by the level one synchronous transport module (stm-1). 3.15 state bit rates for the itu-t g.707 **SDH model structures**.

Range
Calculations Total bytes per frame, The number of frames per second, The frame bit rate, The payload bit rate. **Optical Fibre Benefits** Low transmission loss, immunity to electromagnetic interference, electrical isolation, small size and weight, signal security. **Optical Fibre Drawbacks** High installation costs, special test equipment is often required, cannot carry electrical power. **Time division multiplexing Systems** Synchronous, statistical. **Data Transmission Multiplexing Systems** Synchronous, asynchronous, plesiochronous **Digital Carrier Systems** Synchronous Optical Network (SONET), Synchronous Digital Hierarchy (SDH). **Traffic** Voice, IP packets, ATM cells. **PDH traffic classes** 1.5, 2, 6, 34, 45 and 140 Mbps **SDH model structures** STM-1, STM-4, STM-8, STM-12, STM-16

Guidance
3.3 Learners can demonstrate frame structures by drawing a block diagram.

Learning outcome
4. end systems
Assessment criteria – Practical
The learner can: 4.1 source information on vendor end systems and international standards relating to end systems technologies.
Assessment criteria – Knowledge
The learner can: 4.2 identify **parameters** that determine the suitability of one end system over another 4.3 list technologies that support **end systems** 4.4 identify **methods** of connecting equipment to a network 4.5 describe **user-friendly systems** connected to networks 4.6 compare command line-based systems to GUI-based systems 4.7 describe mainframe computer systems 4.8 identify the main differences and similarities between mainframe and client server networks 4.9 describe client-server computer systems and compare a client server computer system to a peer-to-peer computer system. 4.10 explain web-server technologies and identify **software** that

provides web-server services

4.11 describe the voice over internet protocol (VOIP).

4.12 state advantages of VOIP over conventional telephone systems

4.13 describe potential issues which relate to the implementation of VOIP

4.14 identify technologies that relate to end systems in different **fields**

4.15 describe the impact of information and communication technologies (ICTS) on society and the individual

4.16 describe the concept of 'cloud computing'

Range

Parameters

Total cost of ownership, reliability, compatibility, vendor loyalties, political correctness, performance benchmarks

End systems

Telephones, personal computers (PCs), Electronic Point of Sales (EPOSs), Automatic Teller Machines (ATM), printers, entry systems

Methods

Cable, wireless, infrared, bluetooth

User-friendly systems

Graphical User Interface (GUI), touch screens, fingerprint recognition, iris recognition

Software

Server-side solution - Common Gateway Interface (CGI), Client-side solution - JavaScript

Issues

PBX to PBX, total Internet Protocol (IP) solution, integration with legacy systems, Quality of Service (QoS), latency, jitter

Fields

Audio and video signal processing, broadcast systems, surveillance systems, telemetry, flight control

Learning outcome
5. network management
Assessment criteria – Practical
The learner can: 5.1 perform essential administrative **network tasks** 5.2 use **software tools** to monitor network traffic 5.3 analyse **results** presented by software tools 5.4 give management **permissions** for accessing hardware 5.5 source information relating to network management
Assessment criteria – Knowledge
The learner can: 5.6 describe **issues** that relate to the management of a computer network 5.7 explain why large and complex networks require automated management tools 5.8 define a network management system (NMS) 5.9 describe **elements** of an NMS 5.10 explain the **function** of a management information base (MIB) 5.11 describe the operation of **network management protocols** and their reporting mechanisms 5.12 explain differences between remote monitoring (RMON) and simple network management protocol (SNMP) 5.13 list **equipment** that can be remotely managed 5.14 state examples of network **management software** and explain how it can remotely alter the operating **parameters** of hardware 5.15 explain **terms** commonly associated with the reliability of systems. 5.16 calculate system/network availability provided by mean-time-between-failures (MTBF) and meant-time-to-repair (MTTR) 5.17 outline **security issues** that relate to network management 5.18 explain why it is important to have a network wide security policy, and the role of antiviral software 5.19 describe security implications of a compromised network. 5.20 explain the purpose of **data encryption**

Range
Network Tasks Monitor traffic, maintain documentation, optimisation of network **Software tools** Protocol analysers, network analysers **Results** Collisions, traffic loading, points of failure **Permissions** User profiles, access rights **Issues** Traffic flow, security, performance monitoring, fault detection, problem solving **Elements** Management stations, agents, Management Information Base (MIB), network management protocol, network operations centre **Function** A collection of access points with agents, which report to the management station **Network management protocols** Remote MONitoring (RMON), Simple Network Management Protocol (SNMP) **Equipment** SNMP compliant hubs, switches, routers, personal computers (PCs), modems, intelligent patch panels **Terms** Availability, mean-time-between-failures (mtbf), mean-time-to-repair (mttr), up time, down time, useful life cycle **Management software** HP OpenView, Solstice Sunnet Manager (SSM), BMC patrol **Parameters** Virtual Local Area Network (VLAN) membership, performance thresholds **Security issues** Eavesdropping, intrusion, spoofers, hackers, viruses **Data Encryption** Scrambling of data so that it is unintelligible to unauthorised parties is a means of countering security threats.

Learning outcome
6. internet data center (IDC)
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 6.1 describe **services** offered by an IDC and the **technologies** that underpin them 6.2 list **considerations** for setting up an IDC 6.3 explain the importance of taking into account any unplanned downtime on IDC operations during the planning stage. 6.4 describe **security risks** within an IDC and **methods** for minimising them 6.5 describe **facilities** and **location considerations** for an IDC 6.6 list security issues within an IDC and suggest methods for controlling access 6.7 describe the function of a network firewall in an IDC 6.8 describe **options** for managed hosting in an IDC 6.9 state the different customer **access methods** to an IDC 6.10 identify **issues** that affect customer connectivity to the internet 6.11 describe **factors** that affect the continuity of services within an IDC

Range
Hardware Routers, switches, backup devices, access servers, web servers, Uninterrupted Power Supply (UPS) **Services** Internet access, connectivity, data storage, co-location **Technologies** Modem, Integrated Services Digital Network (ISDN) access, server clustering, load- balancing, data backup systems, fibre channel, traffic shaping **Considerations** Infrastructure, management tools, operating systems, operating network hardware, computing hardware **Security risks** Confidentiality, virus protection, data protection act, encryption, physical access **Methods** Data encryption, high-level physical access control to buildings, anti-virus measures **Facilities** Heat Ventilation Air-Conditioning (HVAC), physical security, fire suppression systems, seismic proof, waterproof, terrorist proof **Location considerations** Located near major public and private interconnects to maximise site performance. Advantage - access to high-speed data links **Options** Virtual Internet Service Provider (ISP), co-hosting **Access methods** Public Switched Telephone Network (PSTN), ISDN, x Digital Subscriber Line (xDSL), leased lines **Issues** Bandwidth, user access ratios, traffic congestion **Factors** 24-hour management systems, redundancy, managed power supply, multiple backup, off-site data backups

Unit 305 Radio Systems

Level:	3
GLH:	117
Aim:	The aim of this unit is to enable the learner to describe the basic principles and concepts involved in the antenna systems used for radio communication, describe the properties and applications of antenna systems and appreciate the factors that effect the propagation of radio signals. It will also enable learners to explain the operational characteristics of radio transmitters and receivers, describe the properties and applications of mobile telecommunication systems and appreciate the properties and characteristics of satellite systems.

Learning outcome
1. fundamentals of electromagnetic radiation
Assessment criteria
The learner can: 1.1 describe electromagnetic (EM) waves in terms of their **elements** 1.2 explain the phase relationship in time between components of the electric (e) field and magnetic (h) field fields for EM radiation 1.3 state the definitions of wave polarisation and wavelength 1.4 state the relationship between velocity, frequency and wavelength, the medium for maximum velocity and its value, 1.5 explain the means by which energised inductance (l) and capacitance (c) provide EM radiation 1.6 explain the conditions for a straight conductor to act as a half-wave ($\lambda/2$) dipole.

Range
Elements Electric (E) field, Magnetic (H) field, direction of propagation, all in space quadrature

Learning outcome
2. antennas and feeder systems
Assessment criteria
The learner can: 2.1 explain how antennas effect energy conversion. 2.2 describe **types** of antenna and their **characteristics**. 2.3 explain the **meaning** of antenna radiation patterns (polar diagrams). 2.4 define antenna **parameters**. 2.5 describe **antenna radiation patterns** in both planes. 2.6 describe **effects** of replacing a dipole by a folded dipole. 2.7 describe the mechanism by which a λ/4 vertical conductor/ unipole can be made to act as a λ/2 dipole 2.8 explain the reason for using a counterpoise. 2.9 describe the method of tuning a unipole. 2.10 explain the **production** of electron movement in a conductor by an EM radiation field. 2.11 describe **factors** that influence simple receiving antenna performance. 2.12 describe **consequences** of adding top capacitance to vertical antennas. 2.13 describe **practical antennas** that use top capacitance. 2.14 explain the operating principles of ferrite rod antennae used in receivers. 2.15 describe **reception properties** of loop antenna considering the field components of the EM wave. 2.16 describe the construction and radiation pattern of a basic rhombic travelling wave antenna. 2.17 distinguish between **types** of antenna feeder. 2.18 describe **transmission and reception consequences** of feeder mismatch at the antenna. 2.19 describe **matching techniques** for balanced and unbalanced feeders. 2.20 describe the use of a balun for connecting a coaxial cable to a λ/2 dipole. 2.21 explain the **limitations** of coaxial feeders and open-wire lines for use with high power transmitters.

Range
Types Travelling wave, standing wave **Characteristics** Broad band, narrow band **Meaning** Plot of the Electric (E) field intensity or the power density as a function of angle in horizontal and vertical planes. **Parameters** Directivity, side-lobe level, driving point impedance, bandwidth

Antenna radiation patterns

Half-wave (λ/2) dipole, λ/2 dipole and reflector, λ/2 dipole, reflector and director

Effects

Increased driving point impedance, increased bandwidth

Production

Electric (E) lines of force parallel to conductor, Magnetic (H) lines of force quadrature to conductor

Factors

Polarisation, tuning

Consequences

Increased effective height, increased radiation resistance, increased radiation energy

Practical antennas

Inverted L antenna, T antenna

Reception properties

Polar diagram, directivity

Types

Balanced, unbalanced

Transmission consequences

Reduced radiation power, feeder standing waves, possible transmitter damage

Reception consequences

Reduced signal, increased noise

Matching techniques

Tuned transformer arrangements, stubs, quarter wave transformers

Limitations

Voltage, current, power, arcing

Guidance
2.3 Learners can use diagrams to explain radiation patterns 2.5 Learners can use diagrams to describe radiation patterns 2.15 Learners can use diagrams to describe the radiation patterns

Learning outcome
3. terrestrial radio propagation
Assessment criteria
The learner can: 3.1 describe **radio bands** in terms of frequency and wavelength. 3.2 describe radio wave **propagation paths** in relation to transmission frequency. 3.3 explain transmission parameters of propagation paths 3.4 describe terrestrial limitation for frequencies above 30mhz. 3.5 describe **types of fading** in long range communication. 3.6 explain bandwidth requirements for **radio services**. 3.7 describe typical services for **modes** of propagation. 3.8 calculate the maximum range for effective communication by the space wave under normal atmospheric conditions using a **formula**

Range
Radio bands Very low frequency (v.l.f.), low frequency (l.f.), medium frequency (m.f.), high frequency (h.f.), very high frequency (v.h.f.), ultra high frequency (u.h.f.), super high frequency (s.h.f.), extra high frequency (e.h.f.) **Propagation paths** Ground (surface) wave, space wave, ionospheric (sky) wave, tropospheric wave **Transmission parameters** Frequency, power, propagation range, bandwidth **Types of fading** Multipath, selective **Radio services** Telephony, sound broadcasting, television, facsimile, data **Modes** Ground (surface) wave, space wave, ionospheric (sky) wave, tropospheric wave **Formula** $d \approx 4\sqrt{h_{\mathrm{T}}} + 4\sqrt{h_{\mathrm{R}}}$ where *d* is the total distance between transmitting and receiving antennas in km, h_{T} and h_{R} are the heights in metres of the transmitting and receiving antennas above ground

Learning outcome
4. radio transmitters
Assessment criteria
The learner can: 4.1 explain the requirement for carrier frequency stability. 4.2 list the **main causes** of drift in inductance–capacitance (LC) oscillator circuits. 4.3 explain the **main features** that allow a crystal to replace an LC circuit. 4.4 describe a basic crystal oscillator circuit. 4.5 explain the reason for modulation or keying not taking place in the master oscillator stage of a transmitter. 4.6 explain **reasons** for radio frequency (R.F.) amplification in a transmitter. 4.7 describe the function of the stages in different **radio transmitters.** 4.8 describe the delta matching transformer technique for connecting a transmitter to a dipole or a unipole. 4.9 explain **consequences** of failing to match the transmitter output stage to its load. 4.10 define **modulation factor** (m) for amplitude modulation (am). 4.11 derive the mathematical expression for the **spectral components** of a sinusoidal carrier amplitude modulated by a sinusoidal tone. 4.12 identify **frequencies** of a carrier amplitude modulated by a base band signal.

4.13 calculate the power distribution between the spectral components of an amplitude modulated wave using **formulas**.

4.14 explain which **frequency components** completely provide the signal information in amplitude modulation.

4.15 explain the **recovery process** of the signal information in a single sideband system (SSB).

4.16 compare the **important parameters** of double sideband systems (DSBs) with SSBs

4.17 describe the different types of **amplitude modulated transmitters**

4.18 describe the **main features** by which high-level and low-level modulation differ.

4.19 calculate the modulator output power required for amplitude modulation of an R.F. power amplifier for specified **conditions**.

4.20 describe circuits of high-level and low-level modulation arrangements for different transmitter radio frequency (R.F.) **output stages.**

4.21 define frequency modulation (FM) parameters.

4.22 describe the **components** of the frequency spectrum of FM when the modulating frequency is a single tone f_S.

4.23 explain effects on the frequency spectrum of frequency modulated waves when the **modulating signal parameters** are increased.

4.24 state carson's rule.

4.25 perform calculations using carson's rule and frequency modulation parameters.

4.26 explain the requirement for carrier frequencies to be above 50mhz in frequency-modulated services.

4.27 describe **methods** for producing frequency modulation.

4.28 explain the **principles** of pre-emphasis and de-emphasis.

4.29 explain the effects of frequency multiplication on the **components** of a frequency-modulated signal.

4.30 describe the **stages** of a frequency-modulated transmitter.

Range
Requirement for carrier frequency stability.
International law, adjacent channel interference, receiver retuning
Main causes
Component values subject to temperature variations, power supply variations, mechanical instability
Main features
Stable frequency, accurate frequency, high Q factor
Reasons
Efficient conversion of direct power to signal power, sufficient carrier amplification to effect modulation, sufficient signal power to cover propagation distance
Radio transmitters
Continuous wave (CW), Amplitude Modulation (AM), Double Sideband Systems (DSB), Single Sideband Systems (SSB)
Antennas
Dipole, unipole

Consequences

Radiation power loss, feeder standing waves, transmitter output stage damage

Modulation factor

$m = V_S / V_C$ where V_S is the r.m.s. value of the modulating signal and V_C is the r.m.s value of the carrier.

Spectral components

Carrier, lower side frequency. upper side frequency

Frequencies

Carrier, lower sideband, upper sideband

Formulas

$P_T = P_C + P_{SB}$, $P_T = P_C(1 + m^2/2)$ where P_T is the total power in the wave, P_C is the power in the carrier and P_{SB} is the total power in the sidebands

Frequency components

Carrier, one sideband

Recovery process

Exact generation of original carrier, mixing, filtering

Important parameters

Power distribution, bandwidth, complexity

Amplitude modulated transmitters

DSB, SSB

Main features

Radio frequency chain efficiency, required audio power level

Conditions

Modulation depth, modulated r.f. power amplifier efficiency, modulating amplifier efficiency

Main stages

Audio, carrier generator, buffer, modulator, driver, power amplifier

Output stages

Class B, class C

Frequency modulation parameters

Frequency deviation, peak frequency deviation (f_D), frequency swing, modulation index (μ), rated system frequency deviation (f_{Dmax}), deviation ratio (*D*), maximum modulating frequency (f_{Smax})

Components

Carrier f_C, plus an infinite number of side frequency pairs $f_C \pm nf_S$.

Modulating signal parameters

Frequency, amplitude

Carson's rule

Signal bandwidth $B = 2(f_D + f_S)$, System bandwidth $B = 2(f_{Dmax} + f_{Smax})$

Methods

Direct (varactor diode), indirect (Armstrong)

Principles

Non-linear audio amplification in the transmitter with corresponding non-linear attenuation in the receiver to counteract noise

characteristics of FM

Components

Carrier frequency, peak frequency deviation, bandwidth

Stages

Audio, limiter, pre-emphasis, modulator, oscillators, a.f.c. (automatic frequency control), frequency multipliers, power amplifier, antenna

Guidance
4.3 Learners can use impedance/frequency response graphs to aid description
4.4 Learners can use circuit diagrams to aid description of circuits
4.7 Learners can use block diagrams to describe stages
4.12 Learners can use frequency spectrum diagram to aid identification of frequencies
4.17 Learners can use block diagrams to aid description of differences
4.18 Learners can use block diagrams to aid description of features
4.20 Learners can use circuit diagrams to aid description of circuits
4.27 Learners can use diagrams to aid description of methods
4.28 Learners can use of diagrams to explain principles
4.30 Learners can use of block diagrams to describe stages

Learning outcome
5. radio receivers
Assessment criteria
The learner can:
5.1 explain how a parallel tuned LC circuit achieves selectivity.
5.2 explain the **demodulation process** for am effected by a diode circuit.
5.3 describe the **stages** of a tuned radio frequency (TRF) receiver.
5.4 explain the presence of the **main frequency components** in the output signal when two different frequencies f_1 and f_2 are present at the input of a device having a square-law characteristic.
5.5 explain the **frequencies** of the output signal when two different frequencies f_1 and f_2 are multiplied together
5.6 describe the result of heterodyning with two radio frequency (R.F.) carriers.
5.7 describe the **process features** for obtaining a fixed intermediate frequency (I.F.) in a superheterodyne receiver.
5.8 explain **benefits** of carrying out amplification at a fixed frequency prior to demodulation.
5.9 define **forms of interference** in a superheterodyne receiver.
5.10 explain **factors** that determine the level of **forms of interference**
5.11 explain the **reasons** for an R.F. amplifier in a receiver
5.12 calculate the **corresponding radio frequencies** for values of I.F.
5.13 explain features of receiver performance.
5.14 explain **reasons for the input signal-to-noise** determining the

usefulness of the output signal information.

5.15 express **signal parameters** in **logarithmic units** and perform relevant calculations.

5.16 calculate image frequencies for **parameters values**.

5.17 describe a single superheterodyne receiver for **different types of modulation**.

5.18 describe means of converting from 2-wire to 4-wire working in a two-way radio communication system

5.19 explain principles of **types of automatic gain control** (A.G.C).

5.20 define receiver parameters.

5.21 describe **stages** of an am communications receiver.

5.22 describe oscillator tracking error.

5.23 describe different **tracking methods**.

5.24 explain I.F. bandwidth requirements for different **am services**.

5.25 describe values for I.F. on **frequency bands**.

5.26 explain the need for limiting prior to FM detection.

5.27 explain the purpose of a frequency discriminator.

5.28 explain the consequence of non-linearity in discriminator response

5.29 explain the operation of **discriminator circuits**.

5.30 explain the **reasons** for the wide I.F. bandwidth in FM receivers and explain the consequence when not met.

5.31 describe the **stages** of an FM receiver.

5.32 explain capture effect in FM reception.

Range

Demodulation process

Rectification, filtering

Stages

Antenna, Tuned r.f. amplifier, diode demodulator, audio amplifier, output transducer, mixer, i.f. amplifiers, limter, discriminator, de-emphasis, mixers , DSB and SSB detectors, BFO, a.g.c

Main frequency components

$f_1, f_2, f_1 \pm f_2$

Frequencies

$f_1 \pm f_2$

Process features

Variable input radio frequency, variable local oscillator frequency, ganging, mixing, filtering

Benefits

Stable fixed high gain, stable fixed slectivity

Forms of interference

Image (second) channel, adjacent channel

Factors

Image channel: r.f. amplifier selectivity, choice of i.f.

Adjacent channel: choice of i.f.

Reasons

Improvement of signal-to-noise, reduction of image channel interference, prevention of local oscillator radiation.

Corresponding radio frequencies

Local oscillator range, r.f. band

Features of receiver performance.

Signal-to-noise, selectivity, gain

Reasons for the input signal-to-noise

Noise accumulation from input to output, corresponding deterioration of signal-to-noise

Signal parameters

signal power, noise power, attenuation, gain, signal-to-noise

Logarithmic units

dB, dBm

Parameters values

Local oscillator range, r.f. band, i.f.

Different types of modulation

Amplitude Modulation (AM), Carrier Wave modulation (CW)

Types of automatic gain control

Simple, delayed

Receiver parameters

Sensitivity, adjacent channel selectivity, image rejection ratio, output signal-to-noise

Tracking methods

Two-point, three-point

AM Services

DSB broadcast, DSB telephony, SSB telephony, CW,

Frequency bands

m.f., h.f., v.h.f.

Discriminator circuits

Foster-Seeley, ratio

Reason

Dependence on both modulating frequency, frequency deviation

Guidance

5.2 Learners can use circuit diagrams to aid explanation of process

5.17 Learners can use block diagrams to aid description of superheterodyne receivers

5.18 Learners can use block diagrams to aid description of means of conversion

5.21 Learners can use block diagrams to aid description of stages

5.28 Learners can use sketch diagrams or graphs to aid explanation of consequences

5.29 Learners can use sketch drawings to aid explanation of operation

5.31 Learners can use block diagrams to aid description of stages

Learning outcome
6. mobile telecommunications systems
Assessment criteria
The learner can: 6.1 describe **principles and concepts** involved in mobile telecommunication systems 6.2 describe **features** of mobile telecommunications. 6.3 state frequency bands designated for different **mobile radio systems**. 6.4 distinguish between private and public mobile telecommunication systems in terms of their different **operation** and **user groups**. 6.5 describe the structure of a cellular mobile radio system. 6.6 describe concepts of clusters and **frequency re-use** in cellular systems. 6.7 explain **multiple access systems** in mobile telecommunication systems. 6.8 describe **problems** associated with multiple path propagation in mobile telecommunication systems and describe **techniques** used to combat them 6.9 explain **requirements for error protection** over the mobile air interface and describe the **protection schemes** used to combat errors. 6.10 explain **requirements for encryption** over the air interface. 6.11 explain why **areas** covered by private mobile radio (PMR) systems depend on application. 6.12 describe PMR and public access mobile radio (PAMR) systems. 6.13 describe terrestrial trunked radio (tetra) system **components**, **interfaces** and **operational features**. 6.14 describe **units** forming a public land mobile network (PLMN). 6.15 explain **features** of mobility management in a PLMN. 6.16 explain the reason and **conditions** when a mobile cellular telephone mobile station (MS) identifies itself to the nearest base station (BS). 6.17 state **reasons for a handover** taking place in a PLMN. 6.18 describe factors that determine cell size in a PLMN. 6.19 describe **methods** of increasing cell capacity. 6.20 state **limitations** of second generation (2g) PLMN data services. 6.21 explain **advantages** of packet switching compared to circuit switching for mobile data applications. 6.22 describe **time slot combination schemes** used to provide higher data rates in time division multiple axis (TDMA) systems. 6.23 describe how modification to the air interface modulation scheme of global system for mobile (GSM) communications by enhanced data rates for GSM evolution (edge) facilitates higher data rates. 6.24 state **implications** for the introduction of edge into existing GSM networks. 6.25 describe **features of the 3g** air interface.

Range
Principles and concepts Radio transmission medium, ground wave components, mobile transceiver units, fixed transceiver base stations, omnidirectional antennas, coverage determined by base station antenna height and power **Features** Mobile units, fixed base station(s), transceivers, radio medium, omnidirectional antennas, **Mobile radio systems** Private Mobile Radio (PMR) systems, Public Land Mobile Network (PLMN) systems **Operation** PMR: non-cellular, limited coverage area, limited number of base stations, semi-duplex communication, no link to PSTN PLMN: Cellular, national coverage area, multiple base stations, duplex communication, links to PSTN **User groups** PMR: emergency services, armed services taxi services, businesses PLMN: general public **Frequency re-use** Limited frequency availability, same set of frequencies used in each cluster **Multiple access systems** Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) **Problems** Fading, mobile movement **Techniques** Space diversity, frequency diversity, polarisation diversity **Requirements for error protection** Nature of radio propagation, multipath fading, exacerbated by movement of mobile, interference **Protection schemes** Forward Error Correcting (FEC) codes, equalisation, interleaving **Requirement for encryption** User and network authentication, user information protection, use of temporary identities **Areas** Local, regional, national **Components** Mobile stations, line stations, Switching and management infrastructure **Interfaces** Radio, Direct mode radio, line station, intersystem, terminal equipment, network management **Operational features** Trunking, frequency bands, access methods, carrier spacing, modulation, channels per carrier **Units** Mobile Station (MS), Base Transceiver Station (BTS), Base Station

Controller (BSC), Mobile Switching Centre (MSC), Home Location Register (HLR), Visitor Location Register (VLR), AUthentication Centre (AUC), Equipment Identity Register (EIR)

Features

Location registration, location updates, roaming, paging, security

Conditions

Regularly when switched on, whether or not a call is in progress

Reasons for handover

Cell capacity exhausted, mobile moving to different cell, quality of service deterioration, service request not met by present channel

Factors that determine cell size

Traffic density, transmitter power, cluster size, terrain nature

Methods

Sectorisation, cell splitting

Limitations

Slow data rate, designed for voice not data, circuit switched,

Advantages

Less connection time, fewer resources tied up, transmission mode more efficient

Time slot combination schemes

High Speed Circuit Switched Data (HSCSD), General Packet Radio Service (GPRS)

Implications

Effective Third Generation (3G) data rates, GSM considered a 3G technology

Features of 3G

Frequency bands, carrier spacing, modulation, coding, frequency re-use

Guidance
6.5 Learners can use diagrams to aid description of structure
6.6 Learners can use diagrams to aid description of clusters
6.13 Learners can use diagrams to aid description of systems
6.14 Learners can use diagrams to aid description of units
6.19 Learners can use diagrams to aid description of methods

Learning outcome
7. satellites
Assessment criteria
The learner can: 7.1 describe **applications** for satellites. 7.2 describe classes of **orbits** used by satellites. 7.3 explain **advantages** and **disadvantages** of the geostationary orbit. 7.4 state the distance in km above the earth's surface of a satellite in geostationary orbit. 7.5 calculate signal propagation delay for satellites in geostationary orbits. 7.6 describe **sources of noise** that are likely to affect communication via a satellite in geostationary orbit.

7.7	explain **mechanisms** for frequency re-use in satellite systems.
7.8	describe satellite **subsystems** in geostationary orbit.
7.9	explain satellite multiple access systems.
7.10	explain the effects of **severe weather conditions** on communication links with geostationary satellites.

Range

Applications

Communication (point-to-point, military and mobile), data communication, meteorological (weather), geophysical surveying, surveillance (spy), navigational aids, television and radio broadcasting

Orbits

Elliptical, low earth, polar circular, geostationary

Advantages

Always in view, no need for complicated tracking systems, no breaks in transmission

Disadvantages

Weak signals on reception, considerable propagation delay, communication affected by earth and lunar eclipses, no coverage of polar regions, more complicated launch vehicles required

Sources of noise

Solar radiation, cosmic background radiation, terrestrial radiation, sky noise, radio emitting stars, nebulae radiation

Mechanisms

Different polarisations, spatially separated shaped satellite beams

Subsystems

Antenna, power, communication, structural, thrust, tracking, telemetry and command

Multiple access systems

Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA)

Severe weather conditions

Wind, snow, fog, rain

Guidance

7.2 Learners can use diagrams to aid description of classes of orbits

Unit 306 Programming principles

Level:	3
GLH:	114
Aim:	This unit covers the fundamentals of programming such as the components, procedures and logical structures of computers. The unit also covers basic programming concepts such as data types and programming languages.

Learning outcome
1. fundamentals of programming
Assessment criteria – Practical
The learner can: 1.1 load and execute a program using a personal computer 1.2 confirm that a program is executing on a personal computer 1.3 stop and remove a program from a personal computer
Assessment criteria – Knowledge
The learner can: 1.4 describe the purpose of computer **components** 1.5 describe **procedures** for loading**,** executing and removing programs 1.6 describe **logical structures** of a computer 1.7 explain how **data handling** is performed in the central processing unit (CPU) 1.8 state the purpose of **registers** used during the execution of a program 1.9 describe **instructions/commands** used in low and high-level programming **languages** 1.10 explain the **importance** of using commenting and informative labelling when writing a program 1.11 explain the instruction/command lines of **programs** 1.12 analyse **programs** and state their purpose 1.13 explain how programming **languages** would be **implemented** on a computer system.

Range
Components Disk storage, Random Access Memory (RAM), Read Only Memory (ROM), Central Processing Unit (CPU), Input/Output (I/O) devices **Procedures** Input, load, execute, stop, remove/delete **Logical Structures** Arithmetic logic unit (ALU), address, data, control bus interconnections, clock, registers **Data Handling** Data to be processed, instructions to be decoded **Registers** Instruction, program counter, memory address, accumulator, status (condition code), stack pointer **Instructions/commands** Arithmetic, logical, branch, input/output (I/O) **Languages** Machine code, assembly, high-level **Importance** Multi-programmer integration, debugging, to assist the understanding of others **Program(s)** Machine code, assembly, high-level **Languages** High-level languages - C, Basic, VB, Java, Pascal, Cobol Low-level languages - Machine code, Assembly **Implemented** Compiled, interpreted, assembled

Guidance
1.4 & 1.6 Learners should be able to explain with the use of block diagrams

Learning outcome
2. basic programming concepts
Assessment criteria – Practical
The learner can: 2.1 input html web pages using a text editor 2.2 test html web pages using a personal computer (pc) 2.3 **edit** and re-test html web pages
Assessment criteria – Knowledge
The learner can: 2.4 explain **data types** 2.5 describe how programming achieves arithmetic, logical and relational operations 2.6 describe **program structures** 2.7 explain the use of **program controls** 2.8 compare and contrast the use of **subprograms** 2.9 describe basic program design components 2.10 describe **components** of a program specification 2.11 explain detailed program **specifications** 2.12 explain flowcharts and algorithms, used to create pseudocode for simple **routines** 2.13 explain differences between top-down and bottom-up designs 2.14 explain design **processes** for a top-down or bottom-up program design 2.15 compare and contrast basic **concepts** of procedure and object-oriented programming (oop) 2.16 describe **components and features** of an object-oriented program. 2.17 describe **properties** of **low-level languages** and **high-level languages** 2.18 explain the meaning of fourth generation languages (4gl). 2.19 describe features of **4gl** 2.20 describe types of **databases** 2.21 describe **advantages** and **disadvantages** of database management systems (DBMS) 2.22 describe the **use of structured query language (sql)** in relation to databases. 2.23 explain properties of **display coding** (tagging) languages 2.24 explain **features** of the html tagging language 2.25 write coding for basic web pages

Range
Edit Text colour, font size, font type, add picture, add radio button, webpage link **Data types** Integers, real numbers (floating-point representation), character strings, Boolean operators. **Program structures** Declaration, execution, termination **Program controls** Sequences, selections, repetitions **Subprograms** Subroutines, functions **Components** Aims, programming methods, development stages, documentation **Specifications** Reliability, maintainability, portability, readability, re-usability, efficiency, development time, costs **Specifications** Input, output, performance, security **Routines** Arithmetical problems, logical problems, keyboard operation **Processes** A simple progam specification. **Concepts** Re-usability, sharing code, maintainability, semantics, dealing with complex problems **Components and features** Objects, encapsulation, instance, class, subclass, inheritance, delegation, relationship **Properties** Structure, syntax, inbuilt library functions, OOP, Procedural, compiled, interpreted, assembled, interactive, graphical interface, application **Low-level language** Machine code, assembly **High-level language** C, Basic, VB, Java, Pascal, Cobol **4GL** SQL, FOCUS, Metafont, Mathematica NATURAL **Databases** Flat file, hierarchical, relational, distributed, network, object oriented **Advantages** Improved data sharing, improved data security, better data integration, minimised data inconsistency, improved data access, improved data access, improved decision making, increased end-user productivity. **Disadvantages** Increased costs, management complexity, frequent upgrade/replacement cycles

Use of Structured Query Language (SQL)

Database and table creation, fetching data from a database table

Display coding

Standard Generalized Markup Language (SGML), Hyper Text Markup Language (HTML), Extensible Markup Language (XML).

Features

Structure, coding (text manipulation, page formatting, lists, images, tables, forms, frames)

Guidance
2.13 – 2.14 Learners should be able to explain with the use of block diagrams

Unit 307 Advanced mathematics

Level:	3
GLH:	60
Aim:	The aim of this unit is to enable the learner to advance and broaden the understanding of mathematics, acquire additional mathematical knowledge (not mandatory) for application to diploma option units in the topic areas of radio systems and programming and to gain sufficient mathematical knowledge to proceed to the first year of a telecommunications or related degree course after successful completion of the diploma.

Learning outcome
1. linear equations and transposition
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 1.1 solve linear equations in one unknown, including brackets and fractions 1.2 form and solve linear equations 1.3 transpose formulae containing a root or power 1.4 transpose formulae in which the subject appears in more than one term

Guidance
1.3 – 1.4 Formulae for example transpose; $k = \frac{1}{2}mv^{2,}$ for v $V = \frac{4}{3}\pi r^3$ for r $a = \frac{b}{1+b}$ for b $\frac{D}{d} = \sqrt{\left(\frac{f+p}{f-p}\right)}$ for p

Learning outcome
2. quadratic functions
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 2.1 factorise quadratic expressions, including perfect squares and the difference of two squares 2.2 solve quadratic equations with real roots by factorisation and by quadratic formula 2.3 determine quadratic equations from their two roots 2.4 apply quadratic equations to practical problems

Guidance
2.4 Practical problems for example linearly accelerated motion, second order chemical reactions

Learning outcome
3. linear law fitting
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 3.1 identify dependent and independent variables 3.2 state the relationship between two variables which are directly proportional 3.3 state the relation between two variables which are inversely proportional 3.4 calculate proportionality constant for direct and inverse proportion 3.5 solve problems involving **common laws** 3.6 identify coordinates from experimental data which obeys **linear law** 3.7 plot co-ordinates and estimate the best fit straight line 3.8 determine gradients of straight lines and the vertical axis intercept 3.9 deduce equations of straight line graphs from the coordinates of two points on the line

Range
Common laws Hooke's, Boyle's, Charles', Ohm's **Linear law** Hooke's

Learning outcome
4. graphs
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 4.1 plot **graphs** with calculated values 4.2 **relate graphs** to communications technology applications 4.3 use linear or log-linear graph paper to plot **straight line graphs** 4.4 determine whether experimental results are related by laws of the type y = ae^{bx} *and* $y = ax^n$ from linear, log-linear and log-log graphs 4.5 estimate constants from linear, log-linear and log-log graphs 4.6 describe the shape of a graph of $log_e\, x$

Range
Graphs y = $e^{\pm ax}$ **Relate graphs** y = ae^{bx} and y = $a\left(1-e^{-bx}\right)$, where *a* and *b* are positive values **Straight line graphs** $y = e^{\pm ax,}$, $y = ae^{bx}$

Learning outcome
5. complex numbers
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 5.1 define a cartesian complex number as z = x + jy, where j is the square root of minus one 5.2 represent complex quantities on an argand diagram in both cartesian and polar forms 5.3 determine the sum, difference and product of two cartesian complex numbers 5.4 define modulus r and argument θ for a polar complex number $z = r\angle\theta$ 5.5 convert between cartesian and polar forms of a complex number 5.6 define the conjugate of a cartesian complex number, with its graphical representation 5.7 divide two cartesian complex numbers by rationalisation of the denominator 5.8 evaluate expressions involving products and quotients of pairs of cartesian complex numbers 5.9 determine the modulus and argument of products and quotients of pairs of different polar complex numbers 5.10 solve equations containing both cartesian and polar complex numbers, including quadratic equations which produce complex roots

Learning outcome
6. trigonometry
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 6.1 use sine and cosine rules to solve triangles 6.2 calculate areas of triangles using a **formula** 6.3 use trigonometry in **practical situations** 6.4 determine values of the trigonometric ratios for angles between $0°$ and $360°$ define tan θ as $\frac{sin\theta}{cos\theta}$ 6.6 plot a sine wave cycle using the vertical projection of a rotating unit radius 6.7 plot a cosine wave cycle using the horizontal projection of a rotating unit radius 6.8 plot **graphs** for $0° < \theta < 360°$ 6.9 describe periodic properties of the trigonometric function 6.10 state the compound angle formulae for sin(a ± b) and cos(a ± b) 6.11 deduce compound angle formulae for sin 2θ and cos 2θ 6.12 deduce that $cos2\theta = 2cos^2\theta - 1 = 1 - 2sin^2\theta$ 6.13 define **angular velocity** and deduce the time period of a sinusoidal waveform 6.14 determine amplitude, frequency, time period and phase angle for the sinusoidal function expressed in the form a sin(ωt + φ) 6.15 show by calculation and graphical verification that the function of the type a sin(ωt + φ) is the sum of a sine term and a cosine term 6.16 express a function of the form a sin ωt ± b cos ωt in the form a sin(ωt + φ) and use this to solve problems

Range
Plot graphs Sin nθ, cos nθ, tan θ, $sin^2\theta$, $cos^2\theta$ **Formula** $\frac{1}{2}ab\,sin\,C$ **Practical situations** Elevation and depression, span roofs, vector addition, reciprocating engine mechanism, idler gears **Angular velocity** ω = 2πf rad/s, T = 2π/ω

Guidance
6.8 Learners are not required to accurately plot, may sketch graphs freehand.

Learning outcome
7. calculus
Assessment criteria – Practical
The learner can: practical not required
Assessment criteria – Knowledge
The learner can: 7.1 state that differentiation of a known function of a variable gives the gradient of the function 7.2 differentiate **simple functions** from first principles 7.3 differentiate **functions** using formulae 7.4 identify the gradient is zero at a maximum or minimum point on a graph 7.5 obtain the second derivative of simple polynomial and trigonometric **functions** and use its sign to distinguish maxima, minima and points of inflexion 7.6 determine **indefinite and definite integrals** 7.7 calculate mean and root mean square values of sinusoidal functions between given limits using integration

Range
Simple functions $y = k,\ y = ax,\ y = ax^2$ **Functions** $y = k,\ y = ax,\ y = ax^2,\ y = ax^3,\ y = a \sin bx,\ y = a \cos bx$ **Indefinite and definite integrals** $y = k,\ y = ax,\ y = ax^2,\ y = ax^3, y = ax^n\ (n \neq -1 \text{and } n = -1), y = a \sin bx, y = a \cos bx$

Unit 308 Maintenance of electrical equipment and systems (elective)

Level:	3
GLH:	80
UAN:	H/503/0420
Credit value:	9
Assessment	This unit will be assessed by an assignment containing centre devised practical tasks and short-answer questions provided by City & Guilds.
Aim:	The unit is concerned with basic electrical theory and electrical components associated with the maintenance of electrical equipment. The learner will understand the operations necessary for the planning and carrying out of maintenance in an industrial and commercial environment.

Learning outcome
The learner will: 1. Understand the components and features of electrical systems
Assessment criteria
The learner can: 1.1 explain **electrical system components** and units in conjunction with system drawings 1.2 explain the **function of electrical components** and the way in which they can be assembled 1.3 identify **components and systems** to meet required functions

Range
Function of electrical components: electromagnets, magnetic materials, iInductors capacitors, electrolytic capacitors, discharge resistors, semi-conductor devices, diodes, thyristor and triac, half and full wave rectification, heat sinks, smoothing circuits, single thyristor circuits, transformers. **Components and systems** containment systems, Busbar systems, underfloor ducting, rising mains, steel wire armoured (SWA) and Mineral Insulated Copper cable (MICC), circuit breakers switches, fuses, isolators supply systems, earthing arrangements TT, TN-S, TN-C-S, lightning protection, no-volt releases, residual current devices. d.c machines ratings, insulation and enclosures. d.c. generators excitation and voltage control. d.c motors, series, shunt & compound, alternating current machines, types- induction and synchronous, construction-cylindrical

and salient pole, power factor correction equipment,single phase motors, series universal, split phase induction start, capacitor start, capacitor start and run, motor starters and motor speed controllers test equipment, insulation resistance testers, low resistance ohmmeters, wattmeters, earth loop impedance and prospective short circuit testers tachometers and stroboscopes.

Learning outcome
The learner will: 2. Be able to plan and prepare for the maintenance operation
Assessment criteria
The learner can: 2.1 evaluate the **extent of work** to be carried out 2.2 describe the current legislation and codes of practice relating to electrical equipment and systems 2.3 carry out a **risk assessment** by listing the procedures and requirements for setting up safe working conditions 2.4 analyse manufacturers' information, related work records, circuit diagrams and other necessary **data** 2.5 identify tools and equipment 2.6 prepare works orders or requisitions

Range
Extent of work: area, safety requirements, equipment, barriers and enclosures, notification of personnel and other workers, Personal Protective Equipment (PPE) **Legislation**: Electricity at Work Regulations, IEE Wiring Regulations, GS 38 **Risk assessment**: method statements, safe isolation procedure, Permit to Work **Data:** manufacturers data, catalogues, internet, component data sheets, availability and assemble of materials, company stores, wholesalers and component suppliers. **Tools and equipment**: hand and power tools, battery operated drills, safety checks.

Learning outcome
The learner will: 3. Be able to carry out monitoring and inspection of maintenance work
Assessment criteria
The learner can: 3.1 carry out **inspection** 3.2 conduct **diagnosis** and carry out repairs 3.3 complete maintenance record

Range
Inspection: on equipment or systems. e.g. visual inspection of plant, cables and containment **Diagnosis and carry out repairs – on faulty system and/or components**

e.g. Faults to lighting, plant containment and other components. Motors and Generators, safe dismantling, recording of faults, install range of electrical systems. containment of oils and greases, protection and storage of parts, wear due to corrosion, erosion and pitting, worn seals, removal and fitting bearings, seals, springs, circlips, manufacture and fitting of gaskets, bench testing of components , maintenance records.

Learning outcome
The learner will: 4. Be able to re-comission the system and restore the work area
Assessment criteria
The learner can: 4.1 **re commissions the system** and adjust as required to working parameters 4.2 **restore work area** to a clean and safe condition upon completion of maintenance 4.3 classify **hazardous substances** and the state the approved method of disposal 4.4 produce a **report** to record the actions taken during hand over.

Range
Re commission system: safety before re-energising, check all systems in place and re-set, prescribed start up procedures, electrical, mechanical and pneumatic/hydraulic checks. **Hazardous substances:** oils, greases, cleaning agents, solvents, insulation, adhesives, fillers, packing, lagging. **Report**: complete maintenance schedules, clear permits to work and sign off, diaries, materials used, record likely future requirements, update maintenance schedule, hand over to authorised personnel.

Guidance
Restore work area. Return reusable materials to store, clean & check tools, return tools to store/storage.

Appendix 1 Relationships to other qualifications

Literacy, language, numeracy and ICT skills development

These qualifications can develop skills that can be used in the following qualifications:

- Functional Skills (England) – see **www.cityandguilds.com/functionalskills**
- Essential Skills (Northern Ireland) – see **www.cityandguilds.com/essentialskillsni**
- Essential Skills Wales – see **www.cityandguilds.com/esw**

Appendix 2 Sources of general information

The following documents contain essential information for centres delivering City & Guilds qualifications. They should be referred to in conjunction with this handbook. To download the documents and to find other useful documents, go to the **Centres and Training Providers homepage** on **www.cityandguilds.com**.

Centre Manual - Supporting Customer Excellence (UK customers only) contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve 'approved centre' status, or to offer a particular qualification, as well as updates and good practice exemplars for City & Guilds assessment and policy issues. Specifically, the document includes sections on:

- The centre and qualification approval process
- Assessment, internal quality assurance and examination roles at the centre
- Registration and certification of learners
- Non-compliance
- Complaints and appeals
- Equal opportunities
- Data protection
- Management systems
- Maintaining records
- Assessment
- Internal quality assurance
- External quality assurance.

Our Quality Assurance Requirements (UK customers only) encompasses all of the relevant requirements of key regulatory documents such as:

- SQA Awarding Body Criteria (2007)
- NVQ Code of Practice (2006)

and sets out the criteria that centres should adhere to pre and post centre and qualification approval.

Access to Assessment & Qualifications provides full details of the arrangements that may be made to facilitate access to assessments and qualifications for learners who are eligible for adjustments in assessment.

Recording Forms for centres and candidates - City & Guilds has developed these recording forms, for new and existing centres to use as appropriate. Alternatively, City & Guilds endorses a number of electronic recording systems. For details, go to the e-Portfolios page on **SmartScreen.co.uk**.

The **centre homepage** section of the City & Guilds website also contains useful information such on such things as:

- **Walled Garden:** this is a free online administration service enabling City & Guilds approved centres to register learners as well as other day-to-day functions quickly and efficiently via the internet. It is the quickest method of only requires authorisation from your Head of Centre to set up a user account. It also contains details of the qualification structure, registration and certification procedures and fees.
- **Events**: dates and information on the latest Centre events
- **Online assessment**: how to register for e-assessments.

Centre Guide – Delivering International Qualifications (International customers only) contains detailed information about the processes which must be followed and requirements which must be met for a centre to achieve 'approved centre' status, or to offer a particular qualification. Specifically, the document includes sections on:

- The centre and qualification approval process and forms
- Assessment, verification and examination roles at the centre
- Registration and certification of learners
- Non-compliance
- Complaints and appeals
- Equal opportunities
- Data protection
- Frequently asked questions.

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www.cityandguilds.com

Useful contacts

UK learners **General qualification information**	**T: +44 (0)844 543 0033** **E: learnersupport@cityandguilds.com**
UK Centres Exam entries, Certificates, Registrations/enrolment, Invoices, Missing or late exam materials, Nominal roll reports, Results	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **centresupport@cityandguilds.com**
International learners and centres General qualification information	Contact your local Branch office. Contact details are available from the City & Guilds website: **www.cityandguilds.com**
Single subject qualifications Exam entries, Results, Certification, Missing or late exam materials, Incorrect exam papers, Forms request (BB, results entry), Exam date and time change	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 F: +44 (0)20 7294 2404 (BB forms) E: **singlesubjects@cityandguilds.com**
International awards Results, Entries, Enrolments, Invoices, Missing or late exam materials, Nominal roll reports	Contact your local Branch office. Contact details are available from the City & Guilds website: **www.cityandguilds.com**
Walled Garden Re-issue of password or username, Technical problems, Entries, Results, e-assessment, Navigation, User/menu option, Problems	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413 E: **walledgarden@cityandguilds.com**
Employer Employer solutions, Mapping, Accreditation, Development Skills, Consultancy	T: +44 (0)121 503 8993 E: **business@cityandguilds.com**
Publications Logbooks, Centre documents, Forms, Free literature	T: +44 (0)844 543 0000 F: +44 (0)20 7294 2413

About City & Guilds

As the UK's leading vocational education organisation, City & Guilds is leading the talent revolution by inspiring people to unlock their potential and develop their skills. We offer over 500 qualifications across 28 industries through 8500 centres worldwide and award around two million certificates every year. City & Guilds is recognised and respected by employers across the world as a sign of quality and exceptional training.

City & Guilds Group

The City & Guilds Group operates from three major hubs: London (servicing Europe, the Caribbean and Americas), Johannesburg (servicing Africa), and Singapore (servicing Asia, Australia and New Zealand). The Group also includes the Institute of Leadership & Management (management and leadership qualifications), City & Guilds Licence to Practice (land-based qualifications), the Centre for Skills Development (CSD works to improve the policy and practice of vocational education and training worldwide) and Learning Assistant (an online e-portfolio).

Published by City & Guilds, a registered charity established to promote education and training

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