Level 3 Rail Engineering Technician Knowledge (6497-03)

Version 1.1 (November 2016)

Qualification Handbook

Qualification at a glance

Entry requirements	Not Applicable
Assessment types	Centre Devised Assignments
Approvals	Fast Track
Support materials	Fast Track Form, centre Devised Assessment Materials
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	GLH	TQT	City & Guilds qualification number	Ofqual accreditation number
Level 3 Diploma in Rail Engineering Technician Knowledge (Traction and Rolling Stock)	360	600	6497-03	603/0401/7
Level 3 Diploma in Rail Engineering Technician Knowledge (Electrification)	360	600	6497-03	603/0401/7
Level 3 Diploma in Rail Engineering Technician Knowledge (Overhead Line Equipment)	360	600	6497-03	603/0401/7
Level 3 Diploma in Rail Engineering Technician Knowledge (Signaling)	360	600	6497-03	603/0401/7
Level 3 Diploma in Rail Engineering Technician Knowledge (Telecommunications)	360	600	6497-03	603/0401/7
Level 3 Diploma in Rail Engineering Technician Knowledge (Track)	360	600	6497-03	603/0401/7

Contents

1 Introduction

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

Area	Description
Who is the qualification for?	These qualifications are aimed at learners aged 16 and above who would like to develop the knowledge and skills that are relevant to a Rail Engineering Operative or a Rail Engineering Technician, either as part of their Apprenticeship or as full time students. Through these qualifications, learners will be introduced to the Rail Engineering Industry and will be able to make an informed decision about what discipline they would like to undertake further training on to take their career forward.
What does the qualification cover?	The railways are a key part of the UK's transport infrastructure for commuting, leisure and business travel, as well as freight services. Rail Engineers are responsible for the safe construction, installation, maintenance and renewal of the railways to provide a safe and reliable railway for customers. These qualifications enable learners to undertake core learning across all areas and specialize in their discipline of choice. The main rail engineering areas covered within these qualifications are: track (including minor works), overhead line, electrification, signaling, telecommunications and traction & rolling stock.
What opportunities for progression are there?	Upon completion of these qualifications learners will have been provided with the self-confidence and motivation to take advantage of the many opportunities for progression and development within the industry, such as: • Carrying out further training in the following areas: track renewals, track maintenance, traction and rolling stock, electrification construction, electrification maintenance and signal and telecommunications. • Go into employment by taking up a Rail Engineering Competence qualification as part of an Apprenticeship to become a competent Rail Engineering Operative or Rail Engineering Technician.

Area	Description
	Improve their leadership and management skills by taking higher level qualifications through the Institute of Leadership and Management.
Who did we develop the qualification with?	This qualification has been developed in collaboration with the Rail Enginering trailblazer group which is led by organisations from the industry including: Transport for London, Network Rail, Alstom Transport Services, Amey, Babcock, Carillion, DB Schenker Rail UK, DEG Signalling, First Group, Hitachi Europe, HS2, MGB Engineering, National Express (c2c Ltd), Siemens, Signalling Solutions, Southwest Trains, Telent Technology Services Ltd, VolkerRail, National Skills Academy for Rail, Eurostar, Merseyrail and Virgin East Coast.
Is it part of an apprenticeship framework or initiative?	These qualifications have been developed as part of the new Apprenticeships for Rail Engineering Operatives and Rail Engineering Technicians which will replace the following SASE frameworks, at Levels 2 and 3: • Rail Infrastructure Engineering • Rail Engineering Overhead Line Construction • Rail Traction and Rolling Stock Engineering.

Structure

Learners must achieve all three units from Mandatory Group A (301 - 303), plus **one** unit from 304 and 305, plus follow the rules for your chosen pathway.

City & Guilds component number	Title
Mandatory Group A	
301	Working safely in within rail engineering
302	Mathematics for engineering technicians
303	Engineering solutions and innovation within the rail industry

Optional Group B

You must choose **one** unit

304	Electrical and electronic principles
305	Mechanical principles

Optional Group C (Track)

You must complete all units

306	Railway infrastructure construction and maintenance
307	Rail technologies

Optional Group D (Traction & Rolling Stock)

You must complete **two** units

308	Rail overground vehicle traction and associated systems
309	Rail overground passenger comfort, safety and security
310	Underground rail vehicle traction and associated systems
311	Underground rail passenger comfort, safety and security

Optional Group E (Electrification)

You must complete **all** units

312	Features and application of electrical machines
313	Rail electrification technologies

Optional Group F (Overhead Line Equipment)

You must complete **unit 314** and **one** unit from 315 or 316

314	Overhead line infrastructure
315	Overhead line technologies (construction)
316	Overhead line technologies (Maintenance)

Optional Group G (Signaling)

You must complete **two** units

317	Functions and characteristics of railway signaling systems
318	Signaling technologies

Optional Group D (Telecommunications)

You must complete **two** units

319	Telecommunications technologies
320	Telecommunications principles

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.

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2 Centre requirements

Approval

If your Centre is approved to offer the qualification 7597 then you can apply for the new Level 3 Rail Engineering Technician Knowledge (6497) approval using the fast track approval form, available from the City & Guilds website.

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.

To offer these qualifications, new centres will need to gain both centre and qualification approval. Please refer to the Centre Manual - Supporting Customer Excellence for further information.

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

Resource requirements

Resources

Centres can use specifically designed areas within a centre to assess, for example, the installation if specialised electrical systems, alignment and setting up if electric motors and driven devices (pumps, compressors, generators). The equipment, systems and machinery must meet industrial standards and be capable of being used under normal working conditions, for example electric motors must have a method of applying sufficient power and not be connected up to show movement.

Centre staffing

Staff delivering these qualifications must be able to demonstrate that they meet the following occupational expertise requirements. They should:

- 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 to the same level as the training being delivered
- have recent relevant experience in the specific area they will be assessing
- have credible experience of providing training.

See also page 12 for details from the assessment strategy on the role of supervisors and managers in the assessment process.

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

Internal quality assurance

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. Centres are responsible for internal quality assurance and City & Guilds is responsible for external quality assurance.

Full details and guidance on the internal and external quality assurance requirements and procedures are provided in the *Centre Manual – Supporting Customer Excellence*, which can be found on the centre support pages of www.cityandguilds.com. This document also explains the tasks, activities and responsibilities of quality assurance staff.

Learner entry requirements

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

Age restrictions

City & Guilds cannot accept any registrations for learners under 16 as these qualifications are not approved for learners under 16.

3 Delivering the qualification

Initial assessment and induction

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

- if the candidate 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.

We recommend that centres provide an induction programme so the candidate fully understands the requirements of the qualification[s], their responsibilities as a candidate, and the responsibilities of the centre. This information can be recorded on a learning contract.

Support materials

The following resources are available for these qualifications:

Description	How to access
Fast Track Forms	www.cityandguilds.com
Centre Devised Assignment Guidance	www.cityandguilds.com
Centre Devised Assignment Forms	www.cityandguilds.com

Recording documents

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

City & Guilds endorses several ePortfolio 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: www.cityandguilds.com/eportfolios.

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 external verifier, before they are used by candidates and assessors at the centre. Amendable (MS Word) versions of the forms are available on the City & Guilds website.

4 Assessment

Summary of assessment methods

Candidates must:

- successfully complete one assignment for each unit

Available assessments/assignments

City & Guilds has written guidance for centres to write their own assessments/assignments.

City & Guilds has developed a template which tutors/assessors can use to write their own assignments.

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.

For this qualification, RPL is allowed and is not sector specific.

Grading of qualification

The Rail Engineering Apprenticeship Employer Group has taken the decision to grade this qualification Pass/Merit/Distinction, through the aggregation of the individual unit assessments graded Pass/Merit/Distinction.

Grading can be of use both as a motivational tool within the learning environment and also to learners presenting evidence of their knowledge to prospective employers.

All assessments must be achieved at a minimum of Pass for the qualification to be awarded. All assessments are graded Pass/Merit/Distinction and contribute equally to the overall qualification grade.

Centres will need to calculate the qualification grade as follows:

- Centre will mark and grade each graded assessment using the model answer mark scheme provided by City & Guilds and available on www.cityandguilds.com

- The grade achieved by a learner will need to be converted into points as follows:

Individual assessment grade	Grade points
Pass	4
Merit	6
Distinction	8

- Grade points for each assessment need to be added together and the overall qualification grade determined using the following conversion table:

Total grade points	Overall qualification grade
28-35	Pass
36-49	Merit
50-56	Distinction

5 Units

Structure of the units

These units each have the following:

- City & Guilds reference number
- Title
- Level
- Guided learning hours (GLH)
- Learning outcomes, which are comprised of a number of assessment criteria

Centres must deliver the full breadth of the range. Specialist equipment or commodities may not be available to all centres, so centres should ensure that their delivery covers their use. This may be covered by a practical demonstration (e.g. video). For the practical assessments for this qualification, centres should ensure that there are sufficient resources to complete the task but are not required to use all the equipment or commodities in the range.

Unit 301 Working safely within rail engineering

Unit level:	Level 3
GLH:	60
Unit aim:	This unit focuses on the essential knowledge required to ensure a comprehensive understanding of the key aspects of health and safety practices and environmental management within a rail workplace.

Learning outcome

The learner will:

1 Understand commercial operations and corporate policies

Assessment criteria

The learner can:

1.1 explain the importance of third party requirements and client confidentiality
1.2 describe the employing organisations policies on ethics, diversity and equality
1.3 describe the implications of not following policies on ethics, diversity and equality
1.4 describe commercial operations and contractual principles between railway organisations.

Range

Commercial operations: Commercial operations and contractual principles between railway organisations, learners must identify the positive and negative implications for railway organisations within their commercial operations and the importance of client confidentiality and the specific third party requirements of partner organisations.

Ethics, diversity and equality: learners should describe their employing organisations policies on ethics, diversity and equality, including the implications of not following policies on ethics, diversity and equality.

Learning outcome

The learner will:

2 Understand health and safety legislation and regulations

Assessment criteria

The learner can:

2.1 describe the responsibilities of the employee and employer with regards to workplace health and safety

2.2 describe the roles and responsibilities of different organisations involved with workplace health and safety

2.3 describe the key features of the relevant health and safety legislation and regulations

2.4 describe the key features of the relevant environmental management legislation and regulations

2.5 explain the possible consequences and cost implications of employees not abiding by legislation and regulations

2.6 explain the possible consequences and cost implications of employers not abiding by legislation and regulations

Range

Key features of legislation: Key features of legislation and regulations (learners must be taught the most recent version):

Legislation e.g. Health and Safety at Work Act 1974, Employment Act 2002, Factories Act 1961, Fire Precautions Act 1971; regulations e.g. Employment Equality (Age) Regulations 2006, Management of Health and Safety at Work Regulations 1999, Provision and Use of Work Equipment Regulations (PUWER) 1998, Control of Substances Hazardous to Health (COSHH) Regulations 2002, Lifting Operations and Lifting Equipment Regulations 1998, Manual Handling Operations Regulations 1992, Personal Protective Equipment at Work Regulations 1992, Confined Spaces Regulations 1997, Electricity at Work Regulations 1989, Control of Noise at Work Regulations 2005, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, Working Time Regulations 1998, Workplace (Health, Safety and Welfare) Regulations 1992, Health and Safety (First Aid) Regulations 1981, Supply of Machinery (Safety) (Amendment) Regulations 2005 (SI 2005/831).

Roles and responsibilities of those involved: employers; employees; Health and Safety Executive (HSE) e.g. span of authority, right of inspection, guidance notes and booklets; others e.g. management, subcontractors, public, suppliers, customers, visitors.

Environmental Management: The basic content and application of current environmental legislation and directives, may include:

- Environmental Protection Act
- Pollution Prevention and Control Act
- Clean Air Act
- Radioactive Substances Act
- Controlled Waste Regulations
- Dangerous Substances and Preparations and Chemical Regulations

The basic content and application of environmental management systems:

- ISO 14000 family of standards, a management tool
- Environmental management – 'What an organisation does to minimise the harmful effects on the environment caused by its activities'
- ISO 14004 provides guidelines on the elements of an environmental management system and its implementation, and examines principle issues involved

- ISO 14001 specifies the requirements for such an environmental management system. Objective evidence is necessary to fulfil these requirements, which can be audited to demonstrate that the environmental management system is operation effectively in conformance with the standard

Learning outcome

The learner will:

3 Know about hazards and risks in the workplace

Assessment criteria

The learner can:

3.1 explain the difference between a risk and a hazard
3.2 describe the methods used to identify hazards in a working environment
3.3 explain how hazards which become risks can be controlled
3.4 describe the process of carrying out a risk assessment within the working environment
3.5 identify control measures as part of a risk assessment

Range

Working environment: Within the working environment: methods to identify hazards e.g. statements, analysis of significant risks, prediction of results or outcomes of those risks, use of accident data, careful consideration of work methods, consideration of the workplace and its potential for harm e.g. confined spaces, working over water or at heights, electrical hazards, chemicals, noise

Control of hazards which become risks: identification of trivial or significant risk; potential to cause harm; choosing appropriate control measures; remove need (design out), use of recognised procedures, substances control, guarding, lifting assessments and manual handling assessments, regular inspection, use of Personal Protective Equipment (PPE), training of personnel, other personal procedures for health, safety and welfare.

Risk assessments: items/area to be assessed e.g. machine operation, work area; five steps (principal hazards, who is likely to be injured/harmed, evaluate the risks and decide on adequacy of precautions, recording findings, review assessment).

Learning outcome

The learner will:

4 Understand methods used when reporting and recording accidents and incidents

Assessment criteria

The learner can:

4.1 explain the importance of reporting and recording accidents and incidents

4.2 describe the procedures used to record and report accidents, dangerous occurrences or near misses

Range

Importance of recording and reporting: why employers keep records of serious accidents, incidents and emergencies; responsibilities of competent persons; cost of accidents e.g. direct, indirect, human consequences; trends e.g. major causes, fatal and serious injury, methods of classification, statistics.

Recording and reporting procedures: regulations on accident recording and reporting e.g. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 1995, accident book, company procedures; procedures to deal with near misses or dangerous occurrences

Unit 302 Mathematics for engineering technicians

Unit level:	Level 3
GLH:	60
Unit aim:	This unit provides the learner an opportunity to acquire knowledge of engineering mathematics

Learning outcome

The learner will:

1 Be able to use algebraic methods

Assessment criteria

The learner can:

1.1 simplify algebraic expressions using the laws of indices and the laws of logarithms

1.2 solve linear equations using straight line graphs

1.3 factorise expressions

Range

Indices and logarithms:
laws of indices: $a^m \times a^n = a^{m+n}$; $a^m/a^n = a^{m-n}$ (m>n); $a^m/a^n = 1/a^{n-m}$ (m<n); $(a^m)^n = (a^n)^m = a^{mn}$

laws of logarithms: (log A + log B = log AB, log An = n log A, log A – log B + log $\frac{A}{B}$) common logarithms (base 10), natural logarithms (base e), exponential growth and decay

Linear equations and straight line graphs: linear equations eg y = mx + c; straight line graph (coordinates on a pair of labelled Cartesian axes, positive or negative gradient, intercept, plot of a straight line); experimental data eg Ohm's law, pair of simultaneous linear equations in two unknowns

Factorisation and quadratics: multiply expressions in brackets by a number, symbol or by another expression in a bracket; by extraction of a common factor eg ax + ay, a(x + 2) + b(x +2); by grouping eg ax – ay + bx – by; quadratic expressions eg $ax2$ + bx + c=0; roots of an equation eg quadratic equations with real roots by factorisation, and by the use of formula

Learning outcome

The learner will:

2 Be able to use trigonometric methods and standard formulae to determine areas

Assessment criteria

The learner can:

2.1 use radian, sine, cosine and tangent functions to solve circular and triangular problems

2.2 solve engineering problems involving the sine and cosine rule

2.3 use standard formulae to find surface areas and volumes of regular solids

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Range

Algebraic expressions: Circular measure: radian; degree measure to radians and vice versa; angular rotations (multiples of π radians); problems involving areas and angles measured in radians; length of arc of a circle ($s = r\theta$); area of a sector ($A = \frac{1}{2} r^2\theta$)

Triangular measurement: functions (sine, cosine and tangent); sine/cosine wave over one complete cycle; graph of tan A as A varies from 0° and 360° (tanA = sin A/cos A); values of the trigonometric ratios for angles between 0° and 360°; periodic properties of the trigonometric functions; the sine and cosine rule; practical problems eg calculation of the phasor sum of two alternating currents, resolution of forces for a vector diagram

Mensuration: standard formulae to solve surface areas and volumes of regular solids eg volume of a cylinder = $\pi r^2 h$, total surface area of a cylinder = $2\pi rh + 2\pi r^2$, volume of sphere = $\frac{4}{3}\pi r^3$ surface area of a sphere = $4\pi r^2$, volume of a cone = $\frac{1}{3}\pi r^2 h$, curved surface area of cone = π r x slant height

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Learning outcome

The learner will:

3 Be able to use statistical methods to display data

Assessment criteria

The learner can:

3.1 produce statistical diagrams, histograms and frequency curves

3.2 determine the mean, median and mode for statistical problems

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Range

Data handling: data represented by statistical diagrams eg bar charts, pie charts, frequency distributions, class boundaries and class width, frequency table; variables (discrete and continuous); histogram (continuous and discrete variants); cumulative frequency curves

Statistical measurement: arithmetic mean; median; mode; discrete and grouped data

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Learning outcome

The learner will:

4 Be able to use elementary calculus techniques

Assessment criteria

The learner can:

4.1 apply basic rules of calculus to solve function by differentiation

4.2 apply basic rules of calculus to solve function by integration

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Range

Differentiation: differential coefficient; gradient of a curve y = f(x); rate of change; Leibniz notation $\frac{dy}{dx}$; differentiation of simple polynomial functions, exponential functions and sinusoidal functions; dx problems involving evaluation eg gradient at a point

Integration: integration as reverse of differentiating basic rules for simple polynomial functions, exponential functions and sinusoidal functions; indefinite integrals; constant of integration; definite integrals; limits; evaluation of simple polynomial functions; area under a curve

Unit 303 Engineering solutions and innovation within the rail industry

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand quality assurance management

Assessment criteria

The learner can:

1.1 define the terms 'quality management' and 'quality assurance'
1.2 describe roles and stages of inspection activities
1.3 explain the key principles of the ISO 9000 series of standards
1.4 describe the elements of quality planning
1.5 describe the key principles of Total Quality Management (TQM)

Range

Quality management and quality assurance: fitness for purpose or meeting customer expectations, quality control as carrying out the procedures identified in quality assurance, quality assurance as the writing and implementing the procedures that ensure quality control takes place, stages of application of quality.

Inspection: any deviation from what is expected, is detected, adjustments can be made to ensure the final quality is in line with customer expectations, the stages of Inspection.

BS EN ISO 9001, an internationally recognised quality assurance standard, involving: involvement of all levels within a company, rationalised systems and procedures, improved costs, improved efficiency, consistent quality of product or service, customer confidence.

Quality planning: establishing quality requirements (customer expectations), allocation of responsibilities (at all levels), agree production times to ensure quality can be met, agree budgets to support quality activities, the setting up of systems to measure quality and report progress, identification and calibration of quality equipment, ability to take corrective actions if non conformity is found

Total Quality Management (TQM): a way of thinking about goals, organisations, processes and people to ensure that the right things are done right first time. This thought process can change attitudes, behaviour and hence results for the better

Learning outcome

The learner will:

2 Understand workplace improvement

Assessment criteria

The learner can:

2.1 identify tools used for continuous improvement within work areas
2.2 identify different wastes within work activities
2.3 explain cost effective ways to eliminate waste
2.4 describe the role of visual management in the workplace
2.5 describe the importance of standardised company documentation in the workplace

Range

Tools used for continuous improvement: flow charts, cause and effect diagrams, check sheets, Pareto charts, histograms, scatter diagrams, control charts

Wastes in the workplace: eg defects, overproduction, over processing, waiting, transportation, inventory, motion, non-utilised talent.

Elimination of wastes: suggest ways how the above list can be eliminated or reduced

Visual management: safety signs, Standard Operating Procedures (SOPs) on boards, improvement notices, company information, types of information (company standards and instructions eg specifications, drawings and records)

Standardised company documents: reduction in error, ease of reporting, capturing the required information, document control.

Learning outcome

The learner will:

3 Understand the basic principles of project management

Assessment criteria

The learner can:

3.1 explain project lifecycle, the stages and factors of a project
3.2 explain project roles and responsibilities.
3.3 explain stakeholder management
3.4 explain how projects are controlled and managed
3.5 identify success factors for projects
3.6 explain why projects are reviewed

Range

Project lifecycle: the stages and factors of a project, Initiation, Planning, Execution and Closure; predecessors, dependents, critical path, deliverables.

Project roles and responsibilities: Project sponsor, project manager, project coordinator, stakeholders, team members

Stakeholder management: Contracts, updates, identification of key staff, communication.

Project control: monitoring: monitor and record achievement, recording and analysing data or performance records, modifying/updating charts/planners, recording project goals and milestones, initial concepts, project solution technical decisions and information

Success factors for projects: Cost, delivery, quality, stakeholder satisfaction

Project are review: Lessons learnt, continuous improvement, deliverables (planned vs actual), costings, Return on Investment (ROI)

Learning outcome

The learner will:

4 Understand problem solving

Assessment criteria

The learner can:

4.1 explain the principles of root cause analysis
4.2 explain the importance of getting to the root cause of problems
4.3 apply a structured procedure to problem solving
4.4 describe factors to be considered when proposing solutions to problems
4.5 explain the importance of monitoring the effectiveness of the corrective actions
4.6 explain the importance of reviewing the problem solving process in order to achieve further improvements within the business

Range

Root cause analysis: Compare root cause to casual factors, identification of all factors, the factor that if removed prevents the fault from occurring.

Approach to problem solving: fishbone diagram, cause and effect, half split, six point technique, input-output, substitution.

Monitoring solutions to problem solving: record solution, effectiveness of solution, potential improvements for future, prevention of future problems.

Unit 304 Electrical and electronic principles

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Be able to use circuit theory to determine voltage, current and resistance in Direct Current (DC) circuits

Assessment criteria

The learner can:

1.1 use DC circuit theory to calculate current, voltage and resistance in DC network

1.2 use a multimeter to carry out circuit measurements in a DC network

Range

DC circuit theory: voltage eg potential difference, Electromotive Force (EMF); resistance eg conductors and insulators, resistivity, temperature coefficient, internal resistance of a DC source; circuit components (power source eg cell, battery, stabilised power supply; resistors eg function, types, values, colour coding; diodes eg types, characteristics, forward and reverse bias modes); circuit layout (DC power source, resistors in series, resistors in parallel, series and parallel combinations); Ohm's law, power and energy formulae eg V = IR, P = IV, W = Pt, application of Kirchhoff's voltage and current laws

DC networks: networks with one DC power source and at least five components eg DC power source with two series resistor and three parallel resistors connected in a series parallel arrangement; diode resistor circuit with DC power source, series resistors and diodes

Measurements in DC circuits: safe use of a multimeter eg setting, handling, health and safety; measurements (circuit current, voltage, resistance, internal resistance of a DC power source, testing a diode's forward and reverse bias)

Learning outcome

The learner will:

2 Understand the concepts of capacitance and determine capacitance values in DC circuits

Assessment criteria

The learner can:

2.1 compare the forward and reverse characteristics of different types of semiconductor diode

2.2 describe the types and function of capacitors

2.3 determine the relationship between the voltage and current for a charging and discharging capacitor

2.4 calculate the charge, voltage and energy values in a DC network for capacitors in series and in parallel

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Range

Capacitors: types (electrolytic, mica, plastic, paper, ceramic, fixed and variable capacitors); typical capacitance values and construction (plates, dielectric materials and strength, flux density, permittivity); function eg energy stored, circuits (series, parallel, combination); working voltage

Charging and discharging of a capacitor: measurement of voltage, current and time; tabulation of data and graphical representation of results; time constants

DC network that includes a capacitor: eg DC power source with two/three capacitors connected in series, DC power source

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Learning outcome

The learner will:

3 Know the principles and properties of magnetism

Assessment criteria

The learner can:

3.1 describe the characteristics of a magnetic field

3.2 describe the relationship between flux density (B) and field strength (H)

3.3 describe the principles and applications of electromagnetic induction

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Range

Magnetic field: magnetic field patterns eg flux, flux density (B), Magneto motive Force (MMF) and field strength (H), permeability, B/H curves and loops; ferromagnetic materials; reluctance; magnetic screening; hysteresis

Electromagnetic induction: principles eg induced Electromotive Force (EMF), eddy currents, self and mutual inductance; applications (electric motor/generator eg series and shunt motor/generator; transformer eg primary and secondary current and voltage ratios); application of Faraday's and Lenz's laws

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Learning outcome

The learner will:

4 Be able to use single-phase alternating current (AC) theory.

Assessment criteria

The learner can:

4.1 use single phase AC circuit theory to determine the characteristics of a sinusoidal AC waveform

4.2 determine the inputs and outputs of a single phase AC circuit

Range

Single phase AC circuit theory: waveform characteristics eg sinusoidal and non-sinusoidal waveforms, amplitude, period time, frequency, instantaneous, peak/peak-to-peak, Root Mean Square (RMS), average values, form factor; determination of values using phasor and algebraic representation of alternating quantities eg graphical and phasor addition of two sinusoidal voltages, reactance and impedance of pure R, L and C components AC circuit measurements: safe use of an oscilloscope eg setting, handling, health and safety; measurements (periodic time, frequency, amplitude, peak/peak-to-peak, RMS and average values); circuits eg half and full wave rectifier

Unit 305 Mechanical principles

Unit level:	Level 3
GLH:	60
Unit aim:	This unit gives apprentices the opportunity to extend their knowledge of mechanical principles and to apply them when solving engineering problems.

Learning outcome

The learner will:

1 Be able to determine the effects of loading in static engineering systems

Assessment criteria

The learner can:

1.1 calculate the magnitude, direction and position of the line of action of the resultant and equilibrant of a non-concurrent coplanar force system

1.2 calculate the support reactions of a simply supported beam

1.3 calculate the induced direct stress, strain and dimensional change in a component subjected to direct uniaxial loading and the shear stress and strain in a component subjected to shear loading

Range

Non-concurrent coplanar force systems: graphical representation e.g. space and free body diagrams; resolution of forces in perpendicular directions e.g. $Fx = F\cos\theta$, $Fy = F\sin\theta$; vector addition of forces, resultant, equilibrant, line of action; conditions for static equilibrium ($\Sigma Fx = 0$, $\Sigma Fy = 0$, $\Sigma M = 0$)

Simply supported beams: conditions for static equilibrium; loading (concentrated loads, uniformly distributed loads, support reactions)

Loaded components: elastic constants (modulus of elasticity, shear modulus); loading (uniaxial loading, shear loading); effects e.g. direct stress and strain including dimensional change, shear stress and strain, factor of safety

Learning outcome

The learner will:

2 Be able to determine work, power and energy transfer in dynamic engineering systems

Assessment criteria

The learner can:

2.1 solve problems that require the application of kinetic and dynamic principles to determine unknown system parameters

2.2 determine the retarding force on a freely falling body when it impacts upon a stationary object and is brought to rest without rebound, in a given distance

Range

Kinetic parameters: e.g. displacement (s), initial velocity (u), final velocity (v), uniform linear acceleration (a)

Kinetic principles: equations for linear motion with uniform acceleration ($v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$, $s = \frac{1}{2}(u + v)t$)

Dynamics parameters: e.g. tractive effort, braking force, inertia, frictional resistance, gravitational force, momentum, mechanical work ($W = Fs$), power dissipation (Average Power = W/t, Instantaneous Power = Fv), gravitational potential energy ($PE = mgh$), kinetic energy ($KE = \frac{1}{2}mv^2$)

Dynamic principles: Newton's laws of motion, D'Alembert's principle, principle of conservation of momentum, principle of conservation of energy

Learning outcome

The learner will:

3 Be able to determine the parameters of fluid systems

Assessment criteria

The learner can:

3.1 calculate the resultant thrust and overturning moment on a vertical rectangular retaining surface with one edge in the free surface of a liquid

3.2 determine the up-thrust on an immersed body

3.3 determine the thermal efficiency of a heat transfer process from given values of flow rate, temperature change and input power

3.4 use the continuity of volume and mass flow for an incompressible fluid to determine the design characteristics of a gradually tapering pipe

Range

Thrust on a submerged surface: hydrostatic pressure, hydrostatic thrust on an immersed plane surface ($F = \rho\ g\ A\ x$); centre of pressure of a rectangular retaining surface with one edge in the free surface of a liquid

Immersed bodies: Archimedes' principle; fluid e.g. liquid, gas; immersion of a body e.g. fully immersed, partly immersed, determination of density using floatation and specific gravity bottle methods

Flow characteristics of a gradually tapering pipe: e.g. volume flow rate, mass flow rate, input and output flow velocities, input and output diameters, continuity of volume and mass for incompressible fluid flow

Learning outcome

The learner will:

4 Be able to determine the effects of energy transfer in thermodynamic systems

Assessment criteria

The learner can:

4.1 calculate the dimensional change when a solid material undergoes a change in temperature and the heat transfer that accompanies a change of temperature and phase

4.2 solve problems that require application of thermodynamic process equations for a perfect gas to determine the unknown parameters of the problems

4.3 determine the force induced in a rigidly held component that undergoes a change in temperature

Range

Heat transfer: heat transfer parameters e.g. temperature, pressure, mass, linear dimensions, time, specific heat capacity, specific latent heat of fusion, specific latent heat of vaporisation, linear expansivity; phase e.g. solid, liquid, gas; heat transfer principles e.g. sensible and latent heat transfer, thermal efficiency and power rating of heat exchangers; linear expansion

Thermodynamic process equations: process parameters e.g. absolute temperature, absolute pressure, volume, mass, density; Boyle's law (pV = constant), Charles' law (V/T = constant), general gas equation (pV/T = constant), characteristic gas equation (pV = mRT)

Unit 306 Railway infrastructure construction and maintenance

Unit level:	Level 3
GLH:	60
Unit aim:	This unit provides the learner an opportunity to acquire knowledge of intermediate engineering mathematics

Learning outcome

The learner will:

1 Know the preparatory activities required for the construction of railway track infrastructure

Assessment criteria

The learner can:

1.1 describe the legal and financial framework applicable to a project for a new section of railway infrastructure

1.2 describe the development process required for a new build or renewal within a railway environment

Range

Legal and financial framework: primary legislation eg Railways Act, regulations; funding of new railways eg Design, Build, Finance And Operate (DBFO), Private Finance Initiative (PFI); procedures to acquire land eg compulsory, compensatory

New build or renewal development process: route considerations eg need for service, number of tracks required, impact on the environment (noise, vibration, aesthetic, pollution, sustainability), stability, infrastructure integrity, associated structures (bridges, tunnels and level crossings); public consultation eg public enquiries, protests, environmental regulation, parliamentary approval; health, safety and welfare eg work force and public, legislation/regulations (Health and Safety at Work Act, Construction (Design and Maintenance) Regulations), method statements and safe methods of work, railway safety systems, industry standards (Network Rail, Railway Safety and Standards Board); contract administration eg legal process, selection of contract, contract conditions, methods of measurement

Learning outcome

The learner will:

2 Know the scope of earthwork activities that may be undertaken in association with railway track infrastructure

Assessment criteria

The learner can:

2.1 describe the methodology used for a railway track earthworks project, including the plant and equipment required for a standard track cross section

2.2 describe the importance of track foundation to the load bearing capacity

Range

Earthworks project methodology: site preparation eg advance fencing, geological survey, stripping topsoil, material disposal, haul road; cut and fill eg site specific problems and solutions, use of explosives, borrow pits; embankment construction eg suitable/unsuitable materials for fill, procedures and testing of soil properties as work proceeds; treatment of weak areas eg stabilisation, replacement and drainage techniques; ground water control eg methods of water table control (including vegetation), stability of slopes; forms of subsoil drainage eg patterns used, types of drainage (collector/carrier, open channel, use of interceptors, typical cross sections used); disposal of collected water eg open channel, soakaways, watercourses and drains via catchpits, discharge legislation (Environment Agency)

Learning outcome

The learner will:

3 Understand the forms of construction and material specifications used in railway track infrastructure

Assessment criteria

The learner can:

3.1 explain the essential design principles for track geometry and the importance of wheel rail interface

3.2 describe the construction methods for initial placement and subsequent maintenance activities to ensure track position and geometry

3.3 describe the materials and quality control processes required to ensure the provision of suitable and sustainable track construction material and waste material disposal

Range

Design principles: forms of construction eg light/heavy rail, specification selection (Network Rail (NR) Track Construction Standard SP/TRK 102); typical forms of track eg cross-sections of track types, formation specifications, sand blanket, geotextile; tunnels; walkways; track design considerations eg conventional passenger speed, enhanced passenger speed, transitions, curves, clearances, rolling stock; design standards eg Technical Specification for Interoperability, Track Design Manual (NR/SP/TRK/049), Track Construction Standard (NR/SP/TRK/102)

Construction methods: renewal methods and plant utilisation eg high output, conventional; methods of maintaining gauge clearance and track position (conventional and absolute track geometry); component fixity; stressing of rails; consideration of associated structures

Materials and quality control: sampling and testing of materials and component parts; product specification and approval processes; sustainable sourcing; waste material disposal eg ballast disposal, track recycling systems

Learning outcome

The learner will:

4 Understand track maintenance processes used to identify and correct defects in railways.

Assessment criteria

The learner can:

4.1 describe the maintenance issues that need to be considered to determine rail infrastructure integrity

4.2 explain how rail infrastructure defects are identified and the prescribed remedial action for each

Range

Maintenance issues: fatigue defects eg rail defects; seasonal/environmental eg leaf fall, low/high temperature, snow, flooding; track component failure eg rail, sleeper, fastening; instability of sub-grade or ballast

Identification of rail infrastructure defects: inspection eg visual, vehicles; high speed testing/examination; review of outputs and application of maintenance standards; special inspections eg bridges, tunnels; rail defect classification

Remedial treatments: replacement of failed components; weld repair; grinding; leaf fall removal; remedial correction of defective ballast eg manual/mechanical methods to stabilise weak sub-grade

Unit 307 Rail technologies

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand basic surveying techniques

Assessment criteria

The learner can:

1.1 identify linear surveying terminology and equipment
1.2 identify levelling surveying terminology and equipment
1.3 carry out linear surveys using appropriate equipment to produce drawings
1.4 carry out levelling surveys using appropriate equipment to produce drawings
1.5 identify angular terminology and equipment

Range

Linear surveying terminology: framework; whole to part; well-conditioned; taping; horizontal and slope distances; chainage; running measurements; perpendicular offsets; tie lines; check lines

Linear surveying equipment: tapes; bands; rules; handheld lasers; ancillary equipment

Linear surveying drawings: internal or external survey plotted to scale

Levelling surveying terminology: back sight; intermediate sight; fore sight; reduced level; datum; Ordnance Survey Bench Mark; Temporary Bench Mark; height of collimation; rise and fall; fly levelling

Levelling surveying equipment: automatic levels; tilting levels; water levels; rotating lasers; barcode instruments

Levelling surveying drawings: spot heights on plans; sections

Angular Terminology and equipment: whole circle bearings; azimuth; horizontal angle; zenith angle; angles of inclination

Angular Equipment: optical square; theodolites

Learning outcome

The learner will:

2 Understand materials in the rail environment

Assessment criteria

The learner can:

2.1 describe mechanical, physical, thermal, electrical and magnetic properties of materials used in rail engineering

2.2 describe the effects of processing on the properties and behaviour of materials used in rail engineering

2.3 describe the principles of the modes of failure

Range

Mechanical properties: strength (tensile, shear, compressive); hardness; toughness; ductility; malleability; elasticity; brittleness

Physical properties: density; melting temperature

Thermal properties: expansivity; conductivity

Electrical and magnetic properties: conductivity; resistivity; permeability; permittivity

Effects of processing metals: recrystallisation temperature; grain structure eg hot working, cold working, grain growth; alloying elements in steel eg manganese, phosphorous, silicon, sulphur, chromium, nickel

Effects of processing polymers: polymer processing temperature; process parameters eg mould temperature, injection pressure, injection speed, mould clamping force, mould open and closed time, curing

Effects of processing ceramics: eg water content of clay, sintering pressing force, firing temperature

Effects of processing composites: fibres eg alignment to the direction of stress, ply direction; de-lamination; matrix/reinforcement ratio on tensile strength; particle reinforcement on cements

Effects of post-production use: smart materials eg impact (piezoelectric), electric field (electro-rheostatic), magnetic field (magneto-rheostatic), temperature (shape memory alloys), colour change (temperature or viscosity)

Learning outcome

The learner will:

3 Understand mechanical systems in the rail environment

Assessment criteria

The learner can:

3.1 describe the purpose and application of lubricants

3.2 describe the operation and maintenance of lubrication systems

3.3 describe the operation of seals, packaging and bearings

3.4 describe the operation of different types of cam and follower and linkage mechanisms

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Range

Cams and linkage mechanisms: cams and followers eg radial plate cams, cylindrical cams, face cams, knife edge followers, flat plate followers, roller followers; linkage mechanisms eg slider-crank and inversions, four-bar linkage and inversions, slotted link quick return motion, Whitworth quick return motion

Belt, chain and gear drives: belt drives eg flat, V-section, synchronous, tensioning device; chain drives eg roller (such as single, duplex, triplex), morse rocker-joint, tensioning devices; gear trains eg gear types (such as spur, helical, herring bone, bevel, spiral bevel, hypoid), simple, compound, worm, combinations, epicyclic

Transmission shafts, clutches and brakes: transmission shafts and couplings eg sections (such as solid, hollow), flanged couplings, splined couplings, angle couplings (such as Hooke universal, constant velocity); clutches eg dog, flat plate, conical, centrifugal, fluid couplings; brakes eg friction (such as internal expanding, external contracting), disc, dynamometers (such as friction, fluid, electromagnetic)

Learning outcome

The learner will:

4 Understand the interface between railway systems

Assessment criteria

The learner can:

4.1 describe the basic principles of electricity as applied to railway infrastructure

4.2 describe the fundamental principles of railway signaling

4.3 explain the operation of points and point detection systems

4.4 describe the relationship between track geometry and overhead line geometry

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Range

Importance of cross discipline interface and the importance of the methods of generating and distribution of electricity for the supply of traction. This should include the methods of distribution of electrical supply for signaling and telecommunications and other lineside power supply requirements.

Importance of railway signaling principles applied to either main line or metro systems

Train detection systems:

- •Operation of DC track circuits
- •Operation of advanced track circuits
- •Operation of axle counters

Lineside signaling technology:

- •Multi aspect signals
- •Lineside equipment housing
- •Lineside cables
- •Under track crossings (UTX)
- •Operation of Automatic Warning Systems or similar
- •Operation of Train Protection Warning System (TPWS) or similar

Operation of points:

- •Hand operated points
- •Mechanically operated points
- •Power operated points
- •Detection of points
- •Facing point locks
- •Back drives

Understanding of the provision of electrical continuity of track for signaling and electrical traction requirements (bonding).

Understanding of the requirements of both Overhead Line geometry and DC 3rd/4th Rail traction supply geometry.

Unit 308 Rail overground vehicle traction and associated systems

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand traction and rolling stock suspension systems

Assessment criteria

The learner can:

1.1 describe the design, construction, maintenance and operation of train suspension
1.2 describe the purpose of the different suspension systems fitted to trains
1.3 explain how failed suspension increases damage to both track and vehicles
1.4 compare conventional body/bogie mountings

Range

Design factors: weight, purpose, (passenger, freight, underground), speed, weather (operating), infrastructure setup (track layout, type).

Suspension systems: eg: primary/secondary suspension, ride height, high speed, tilt

Failed suspension: damper fail leakage, cracked springs, increase impact and wear track/wheelflats

Bogie mounting types: bolster airbag bolting, location keys

Learning outcome

The learner will:

2 Understand the fundamentals of traction and rolling stock braking systems

Assessment criteria

The learner can:

2.1 describe the operation of a typical air/electric brake system
2.2 describe how a variable load valve works and what symptoms would become apparent in the event of failure

2.3 describe the various types of friction pad in use on traction and rolling stock

2.4 describe the operation of a wheel slide prevention system

2.5 describe the safety systems that can take over the operation of a train braking system in the event of operator error

2.6 describe why automatic sanding is necessary

2.7 explain the implications to the Train Operating Company (TOC) of a unit in service being unable to release brakes whilst on the line

2.8 explain the use of round train circuits and the implications of their failure.

Range

Braking systems: friction braking, regenerative braking, (round train system/emergency brake loop)

Wheel slide prevention system: wheel probes, toothed wheels, sanding systems, increased adhesion and grip

Safety systems: TPMS, AWS

Unable to release brakes whilst on the line: Impact minutes, reliability calculation, TIN (Train Incident) strike risk, timetable implications

Learning outcome

The learner will:

3 Understand the fundamentals of traction and rolling stock axles, wheels and bearings

Assessment criteria

The learner can:

3.1 describe a typical wheelset, identifying all components

3.2 identify the different types of wheel profile and their specific use

3.3 describe the process of changing out a wheelsets as routine maintenance, identifying all risks associated with the operation

3.4 explain the risks associated with changing out a wheelsets

3.5 describe in situ test and inspection methods for traction and rolling stock wheelsets

3.6 discuss the implications of a 'flat' on a wheelset

3.7 discuss ways in which wheelset life may be extended

3.8 explain the importance of a regular maintenance programme for traction and the implications of a delay in this.

Range

Wheel types: monoblock, wheel profile, wheel rail interface

Bearing types: roller, single lipped, ball, taper, axle bearing failure, frequency, predicative maintenance, rail BAM, condition monitoring

Flats: Poor vehicle ride, cost of taking vehicle 'out of service' for tyre turning

Wheelset life: use of condition based monitoring, use of preventive tyre turning

Maintenance policies: frequency, cost, MTBF

Learning outcome

The learner will:

4 Understand AC electric power collection and transmission

Assessment criteria

The learner can:

4.1 describe the relationship between the design, construction, maintenance and operation of an AC electric powered traction unit

4.2 describe AC traction supply in terms of the relationship between voltage, current and frequency

4.3 explain the construction and function of a typical high speed pantograph

4.4 describe what systems are in place to off load and prevent arc dragging at neutral sections

4.5 describe how an AC vehicle's main transformer works and the need for different voltage outputs

4.6 compare the performance, reliability characteristics and maintenance implications of AC and DC traction motors

4.7 describe the bonding and earth return requirements and arrangements for a typical 25kv traction unit

4.8 explain the principles of rheostatic/regenerative braking

Range

Traction unit types: transformer function, rectifier, regenerative braking, four quadrant chopper

Performance, reliability characteristics of AC traction units: reliable, environmental, reduced maintenance (less intrusive)

Current collection: pantograph (OLE), shoe gear (3rd and 4th rail)

Bonding earthing: earthing to wheels, bonding to ensure train remains safe, capacitor residual power safety

Regenerative braking: resistance

Learning outcome

The learner will:

5 Understand the fundamentals of DC electric power collection and transmission

Assessment criteria

The learner can:

5.1 describe the relationship between the design, construction, maintenance and operation of a DC electric powered traction unit
5.2 describe DC traction supply in terms of the relationship between voltage, current and frequency
5.3 describe typical 750V DC collection equipment
5.4 describe the systems that are in place to off load and prevent arc dragging at section gaps
5.5 describe how the speed of DC traction motors is controlled
5.6 describe the relationship between current, speed and temperature for DC traction motors
5.7 describe the main performance issues resulting from sub-zero temperatures and snowfall
5.8 describe how a traction unit operating on a DC electrified railway may utilise AC traction motors
5.7 describe the earth return and bonding requirements for a typical 750V DC traction unit

Range

Traction unit types: DC powered

Current collection: shoe gear (3rd and 4th rail)

Performance, reliability characteristics of traction units: DC powered

Operational factors of: DC powered, rheostatic/regenerative braking, motor control,

Learning outcome

The learner will:

6 Understand diesel hydraulic and diesel electric power generation and transmission

Assessment criteria

The learner can:

6.1 describe the relationship between the design, construction, maintenance and operation of a diesel powered traction unit
6.2 identify the key internal and external components of a diesel engine
6.3 explain the operation of a diesel engine
6.4 describe how a diesel engines performance is controlled, including how operation of the control system produces a variation in power output
6.5 describe how the performance of a turbo charger affects the performance of a diesel engine
6.6 describe how a diesel hydraulic power unit operates

6.7 describe how a diesel electric power unit operates

Range

Traction unit types: diesel hydraulic and diesel electric power

Performance, reliability characteristics of traction units: diesel hydraulic and diesel electric power less reliable and more maintenance required

Operational factors of: cost, environment

Unit 309 Overground passenger comfort, safety and security

Unit level:	Level 3
GLH:	60
Unit aim:	This unit enables the learner to develop their skills and knowledge in the different types of railway traction and rolling stock doors, toilets and vehicle trim.

Learning outcome

The learner will:

1 Understand passenger safety and security systems

Assessment criteria

The learner can:

1.1 explain the importance of Closed Circuit Television systems and passenger safety systems in terms of passenger security and comfort

1.2 explain the technical requirements and function of components used in a typical Closed Circuit Television system and passenger safety systems

1.3 explain the different recording media used in typical Closed Circuit Television systems

1.4 identify the key components of Passenger Information Systems

1.5 describe the function and operation of Passenger Information System components

1.6 describe of the relationship between passenger alarms and emergency brakes

1.7 explain how automatic announcements are controlled on a typical Passenger Information System

Range

Passenger safety and security systems: e.g. Closed Circuit Television systems, Passenger Information Systems, Information Controller, passenger alarm, Pass Com over-ride kick button, EBL – Emergency Brake Loop.

Function of passenger comfort, safety and security systems: e.g. Closed Circuit Television systems, Heating Ventilation and Air Conditioning (HVAC) Systems, Passenger Information Systems, Information Controller

Key components of Passenger Information Systems: showing all of the including controllers, displays, passenger alarms and on train audio

Learning outcome

The learner will:

2 Understand heating ventilation and air conditioning systems

Assessment criteria

The learner can:

2.1 explain the principles of heat transfer in terms of conduction, convection and radiation
2.2 explain the relationship between temperature and pressure and how this relationship is used in HVAC systems
2.3 describe the components and their function in a typical rolling stock HVAC system
2.4 describe different types of refrigeration
2.5 describe the safety precautions to be used when working on and around HVAC systems
2.6 describe a typical electronic control unit for an HVAC used within rolling stock and any associated maintenance software
2.7 explain the environmental and legal implications of a release of refrigerant into the atmosphere

Range

HVAC system components: compressors, condenser fan, supply air fans, fresh air fans, heater coils, evaporator coils, condenser, Programmable Logic Controller (PLC), control units, DC/DC converter, charging valves, air filters

Types of refrigeration: mechanical, chemical and venturi

Maintaining systems: e.g. fault finding, unit replacement, maintenance planning

FGas regulations

Learning outcome

The learner will:

3 Understand train interior and exterior, saloon and cab door systems

Assessment criteria

The learner can:

3.1 explain the operating principles of electrical and pneumatic doors systems
3.2 explain the components, materials used and operational requirements of exterior cab and saloon doors systems
3.3 describe the electrical/ electronic methods used for the control and operation of exterior cab and saloon door systems
3.4 describe the safety devices fitted to exterior saloon doors and describe the operation of these devices

3.5 explain the term 'wrong side failure' and any implications that such a failure would have on the exterior saloon door system

3.6 demonstrate the ability to fault find on door systems using

3.7 explain the importance of a correct mechanical saloon door set up

3.8 explain the reason for differences between cab back wall doors and standard interior doors

Range

Door systems: saloon doors, cab doors, interior or gangway doors, cab back wall doors, front gangway half door, toilet doors, TMO door

Safety devices: sensitive edge, finger protection rubber, door leaf, manual lock, guide rail, door catch, swivel arm, external emergency access device, Bowden cable, rotary latch mechanism, pneumatic panel, door drive mechanism, door glass

Fault finding: using downloads, diagnostic software, system schematics and MVB analysis if applicable

Correct mechanical saloon door set up: with regard to normal operation, safety implications, impact on the serviceability of door components

Learning outcome

The learner will:

4 Understand train toilet systems

Assessment criteria

The learner can:

4.1 explain the operating principles of a typical toilet system

4.2 explain the components that make up a toilet system and operational requirements of each component

4.3 describe any current legislation with regards to on train toilets and how this effects rolling stock design

4.4 describe any health and safety requirements of working on and changing components in any toilet system

4.5 describe the limitations of using fresh waste water tanks and explain any affect they may have on a TOC's diagram choice

Range

Components: water tank unit, waste water system, toilet, microprocessor

Learning outcome

The learner will:

5 Understand train vehicle trim

Assessment criteria

The learner can:

5.1 describe a typical passenger counting system and explain the reasons why a TOC would choose to install or use such a system

5.2 explain why a TOC may request that main interior lighting is automatically switched off while a unit is not in service

5.3 describe the required properties of the glazing used on passenger trains in both the cab and saloon areas

5.4 explain the minimum lighting requirements of a passenger train if it were to lose its main source of electrical power

5.5 explain how altering the orientation of interior fittings, such as tables and seating, a TOC can accommodate different numbers of passengers on a typical unit

5.6 describe the generation of the voltage used for passenger charging sockets and explain the relationship between the number of sockets and the rating of any associated MCB

5.7 describe the logistics of maintaining a clean and tidy service for passengers from the perspective of train down time and manpower requirements

Unit 310 Underground rail vehicle traction and associated systems

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand traction and rolling stock suspension and tilt systems

Assessment criteria

The learner can:

1.1 describe the design, construction, maintenance and operation of train suspension
1.2 describe the purpose of different suspension systems
1.3 explain how failed suspension increases damage to both track and vehicles
1.4 compare conventional body/bogie mountings

Range

Design factors: weight, purpose, passenger

Suspension systems: dampers, levelling valves, over heights

Bogie styles: styles, assemblies, shoegear mountings

Learning outcome

The learner will:

2 Understand traction and rolling stock braking systems

Assessment criteria

The learner can:

2.1 describe air/electric brake systems
2.2 describe how variable load valves work and what symptoms would become apparent in the event of failure
2.3 describe the various types of friction pad in use on traction and rolling stock
2.4 describe the operation of wheel slide prevention systems
2.5 describe the safety systems that can take over the operation of a train braking system in the event of operator error

2.6 describe why automatic sanding is necessary

2.7 explain the implications to the Train Operating Company (TOC) of a unit in service being unable to release brakes whilst on the line

2.8 explain the use of round train circuits and the implications of their failure.

Range

Braking systems: Friction, Dynamic, PWM, Brake Safety Systems, Blending

Wheel slide prevention system: system, dump valves, interaction with dynamic brake

Sanding de-icing systems: increase adhesion and grip, triggers for use

Learning outcome

The learner will:

3 Understand traction and rolling stock axles, wheels and bearings

Assessment criteria

The learner can:

3.1 describe typical wheelsets, identifying all components

3.2 Identify different types of wheel profile and their specific use.

3.3 describe the risks associated with changing out wheelsets

3.4 describe in situ test and inspection methods for traction and rolling stock wheelsets

3.5 discuss the implications of a 'flat' on a wheelset

3.6 discuss ways in which wheelset life may be extended

3.7 explain the importance of a regular maintenance programme for traction and the implications of a delay in this.

Range

Wheel types: styles, size, profiles

Bearing types: roller, ball, taper

Maintenance policies: frequency (time/distance)

Couplings: flexible, purpose

Learning outcome

The learner will:

4 Understand AC electric power collection and transmission

Assessment criteria

The learner can:

4.1 describe the relationship between the design, construction, maintenance and operation of an AC electric powered traction unit

4.2 describe AC traction supply in terms of the relationship between voltage, current and frequency

4.3 describe what systems are in place to off load and prevent arc dragging at neutral sections or gaps

4.4 describe how an AC vehicle's main transformer works and the need for different voltage outputs

4.5 describe the operation of a typical AC traction power control system that shows variations to allow for the control of both AC and DC traction motors

4.6 compare the performance, reliability characteristics and maintenance implications of AC and DC traction motors

4.7 explain the principles of rheostatic/regenerative braking

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Range

Traction unit types and system/components: Motor Convertor Module, 3 Phase Inverter, Charging Circuits, Brake Resistor

Maintenance of traction units: types and periods of maintenance regimes used

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Learning outcome

The learner will:

5 Understand the fundamentals of DC Electric power collection and transmission

Assessment criteria

The learner can:

5.1 describe the relationship between the design, construction, maintenance and operation of a DC electric powered traction unit

5.2 describe DC traction supply in terms of the relationship between voltage, current and frequency

5.3 describe typical 630/750V DC collection equipment

5.4 describe the systems that are in place to off load and prevent arc dragging at section gaps

5.5 describe how the speed of DC traction motors is controlled

5.6 describe how 'noise interference' is minimised on a DC Traction Motor circuit

5.7 describe the main performance issues resulting from sub-zero temperatures and snowfall

5.8 describe how a traction unit operating on a DC electrified railway may utilise AC traction motors

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Range

Traction unit types and system/components: Thyristor Control, Filter Circuits, RFI Suppression, Static Converter, Rheostatic and Regenerative Braking.

Maintenance of traction units: Types and periods of maintenance regimes used

Unit 311 Underground rail passenger comfort, safety and security

Unit level:	Level 3
GLH:	60
Unit aim:	This unit enables the learner to develop their skills and knowledge in the different types of railway traction and rolling stock doors, toilets and vehicle trim.

Learning outcome

The learner will:

1 Understand Closed Circuit Television systems

Assessment criteria

The learner can:

1.1 explain the purposes of Closed Circuit Television systems for passengers

1.2 explain the components used and their function in Closed Circuit Television systems

1.3 describe the implications of Closed Circuit Television systems failing and the methods used for fault finding on the system

1.4 explain the reasons for the different types of recording media used in Closed Circuit Television systems

1.5 explain the implications of using a Closed Circuit Television system with respect the privacy of passengers

Range

Purpose of passenger safety and security systems: e.g. Closed Circuit Television systems, Passenger Information Systems (automatic and manual), security and comfort

Maintaining systems: e.g. fault finding (Including the use of digital interrogation devices), unit replacement, maintenance planning

Learning outcome

The learner will:

2 Understand Heating Ventilation and Air Conditioning Systems

Assessment criteria

The learner can:

2.1 explain the principles of heat transfer in terms of conduction, convection and radiation
2.2 explain the relationship between temperature and pressure and how this relationship is used in HVAC systems
2.3 describe the components and their function in typical rolling stock HVAC systems
2.4 describe the air conditioning refrigeration system
2.5 describe the safety precautions to be used when working on and around HVAC systems
2.6 describe typical control units for an HVAC used within rolling stock and any associated maintenance
2.7 explain the environmental and legal implications of releasing refrigerant into the atmosphere

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Range

Function of HVAC systems: heating, ventilation, air conditioning, emergency ventilation.

HVAC systems: components e.g. compressors, condensers, sensors, Control Modules

Maintaining systems: fault finding, unit replacement, maintenance planning,

Operating principles/requirements: thermostatic controls, condition monitoring

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Learning outcome

The learner will:

3 Understand passenger information systems

Assessment criteria

The learner can:

3.1 describe the relationship between passenger alarms and emergency brakes
3.2 describe the function and operation of each of the Passenger Information System components
3.3 explain how automatic announcements are controlled on a typical Passenger Information System
3.4 demonstrate the ability to fault find on the Passenger Information Systems using downloads, system schematics and MVB analysis if applicable
3.5 explain the importance of having a functioning Passenger Information System in terms of passenger safety and comfort
3.6 explain the importance of having a functioning Passenger Information System in terms of passenger safety and comfort

Range

Passenger Information System key components: controllers, displays, passenger alarms and on train audio

System Types: passenger alarm & talkback, cab and saloon audio communications

Learning outcome

The learner will:

4 Understand train door systems

Assessment criteria

The learner can:

4.1 explain the components, materials used and operational requirements of exterior cab and saloon doors systems

4.2 describe the electrical/ electronic methods used for the control and operation of exterior cab and saloon door systems

4.3 list the safety devices fitted to exterior saloon doors and describe the operation of these devices

4.4 explain the term 'wrong side failure' and any implications that such a failure would have on the exterior saloon door system

4.5 demonstrate the ability to fault find on the cab and door systems

4.6 explain the importance a correct mechanical saloon door set up

Range

Function door systems: operator control, emergency control, end door cut out, re-open, passenger control

Design of door systems: Safety Considerations

How door systems are integrated: Interaction of Door Controls

Fault finding: using downloads, diagnostic software, system schematics and MVB analysis if applicable

Correct saloon door set up: with regard to normal operation, safety implications and impact on the serviceability of door components

Learning outcome

The learner will:

5 Understand train vehicle trim

Assessment criteria

The learner can:

5.1 describe the required properties of the glazing used on passenger trains

5.2 explain the minimum lighting requirements of a passenger train if it were to lose its main source of electrical power

5.3 describe the logistics of maintaining a clean and tidy service for passengers from the perspective of train down time and manpower requirements

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Range

Glazing: types and properties, seals, de-misting, draught screens

Function of vehicle trim: safety, customer access prevention

Design of vehicle trim: functionality, fire precautions, safety

Maintenance requirements: cleaning regimes, ambience checks, train preparation

Unit 312 Features and application of electrical machines

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Know the legislation, regulations and standards related to working with electrical apparatus

Assessment criteria

The learner can:

1.1 identify the hazards that may exist when working with electrical apparatus

1.2 describe the control measures that should be used to reduce the risk of harm to self and others when working electrical apparatus

1.3 describe the legislation, regulations and standards that relate to electrical apparatus

Range

Electrical hazards: safe working procedures eg isolation (safe isolation, switch off, lock off, display notices, testing for dead with test lamp and proving unit), earthing, interlocking, warning notices, permit to work; risk assessment when working on electrical apparatus eg hazard evaluation and recording of risk, controlling risk; Personal Protective Equipment (PPE) eg insulated gloves, mats, tools, barriers

Legislation, regulations and standards: eg Health and Safety at Work Act 1974, The Electricity at Work Regulations 1989, Personal Protective Equipment at Work Regulations 1992, Electrical Equipment (Safety) Regulations 1994, Machinery Directives, HSE publications, Codes of Practice, British and International Standards, BS7671 17th Edition IEE Wiring Regulations

Learning outcome

The learner will:

2 Understand Alternating Current (AC) machines

Assessment criteria

The learner can:

2.1 explain the features, characteristics and application of AC motors

2.2 explain the features, characteristics and applications of AC generators

2.3 explain the features, characteristics and applications of transformers

Range

Alternating Current (AC) motors: single and polyphase; construction, principles of operation, starting characteristics and torque; types (induction motors, split-phase, capacitor start, capacitor start and run, shaded pole, universal, variable frequency drives); applications of AC motors eg conveyor belt drives, pumps, machine shop equipment, fixed loads, variable loads

AC generator: types eg single-phase, polyphase; construction and principles of operation; applications eg stand-by generators, remote site generators, vehicle alternators with regulation and rectification

Transformers: principles of operation; efficiency and losses; construction of single and double wound; types eg step up, step down, safety isolating transformer; applications eg incoming mains step down, portable transformer for hand tools, safety isolating transformer for electrical test-bench work, machine power supplies

Learning outcome

The learner will:

3 Understand direct current (DC) machines

Assessment criteria

The learner can:

3.1 explain the features, characteristics and applications of DC motors

3.2 explain the features, characteristics and applications of DC generators

Range

Direct Current (DC) motors: types eg series, shunt, compound (long and short shunt), brushless; construction, principles of operation, starting characteristics and torque; applications eg motor vehicle starters and window operation, toys and models, industrial drives, crane hoists, fixed loads, variable loads

DC generators: construction and principles of operation; production and control of DC voltages and current; applications eg motor vehicles, speed control/feedback systems (tacho-generators)

Learning outcome

The learner will:

4 Know how electrical machine control circuits and systems operate

Assessment criteria

The learner can:

4.1 describe the operation of stop/start/retain relay control circuits for AC or DC machines

Range

Stop/start/retain relay control: relay/contactor with retaining/latching contact; start, stop, overload, 'inch' (non-latching) control; remote stop/start; safety relays for production/manufacturing equipment eg several guards closed sensors, oil level detectors, temperature sensors, body heat (passive infra-red) detectors; control circuits eg AC machine control (Direct On Line (DOL), star-delta, soft start and other solid state techniques such as TRIAC, inverter drives, slip ring rotor resistance control, auto transformer, power factor correction), DC machine control (starting methods and speed control such as face plate, solid state systems); emergency stop eg closed contact device to stop the machine/system from running or starting and turn power off under emergency conditions; emergency stopping eg dynamic braking by either DC injection braking or timed phase reversal, solenoid operated mechanical brakes, instantly stopping the machine

Unit 313 Rail electrification technologies

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand mechanical systems

Assessment criteria

The learner can:

1.1 describe the purpose and application of lubricants
1.2 describe the operation and maintenance of lubrication systems
1.3 describe the operation of seals, packaging and bearings
1.4 describe the operation of different types of cam and follower and linkage mechanisms
1.5 describe the arrangement and operation of transmission shaft and coupling, clutch and brakes
1.6 describe the layout and operation of a pneumatic actuation systems, hydraulic actuation systems and manual handling systems
1.7 describe the layout and operation of power generation plant, refrigeration and air conditioning systems applied to substations

Range

Lubricant purposes and types: purpose eg reduction of frictional resistance, reduction of wear, heat dissipation, prevention of corrosion, prevention of contamination; types eg mineral, vegetable and synthetic oils and greases, graphite, compressed gases, cutting fluids

Lubrication systems and maintenance: operation of lubrication systems eg gravity feed, forced feed, splash lubrication, capillary action, grease cups and nipples, grease packing, compressed air/gas bearings; maintenance eg replenishment and renewal of lubricants, safe storage and handling

Seals, packing and bearings: seals eg rotary lip seals, mechanical seals, piston rings; packing eg packed glands, gaskets, shims; bearings eg plain journal, thrust, ball, roller (such as parallel or tapered), needle

Cams and linkage mechanisms: cams and followers eg radial plate cams, cylindrical cams, face cams, knife edge followers, flat plate followers, roller followers; linkage mechanisms eg slider-crank and inversions, four-bar linkage and inversions, slotted link quick return motion, Whitworth quick return motion. Belt, chain and gear drives: belt drives eg flat, V-section, synchronous, tensioning device; chain drives eg roller (such as single, duplex, triplex), morse rocker-joint, tensioning devices; gear trains eg gear types (such as spur, helical, herring bone, bevel, spiral bevel, hypoid), simple, compound, worm, combinations, epicyclic

Transmission shafts, clutches and brakes: transmission shafts and couplings eg sections (such as solid, hollow), flanged couplings, splined couplings, angle couplings (such as Hooke universal, constant velocity); clutches eg dog, flat plate, conical, centrifugal, fluid couplings; brakes eg friction (such as internal expanding, external contracting), disc, dynamometers (such as friction, fluid, electromagnetic)

Actuation and handling systems: pneumatic and hydraulic actuation systems eg system layout for automated plant and process operations, system components; safety and maintenance; mechanical handling systems eg belt conveyers, roller conveyers, workshop gantry cranes, workstation jib cranes

Steam, refrigeration and air conditioning plant service systems: steam power generation plant eg system layout for power generation and process operations, system components, feed water treatment, safety and maintenance; refrigeration systems eg system layout for vapour compression and absorption systems, refrigerants, system components, safety and maintenance; air conditioning systems eg system layout for full summer and winter cycle air conditioning, system components, safety and maintenance

Learning outcome

The learner will:

2 Understand materials in the rail environment

Assessment criteria

The learner can:

2.1 describe mechanical, physical, thermal, electrical and magnetic properties of materials used in rail engineering

2.2 describe the effects of processing on the properties and behaviour of materials used in rail engineering

2.3 describe the principles of the modes of failure

Range

Mechanical properties: strength (tensile, shear, compressive); hardness; toughness; ductility; malleability; elasticity; brittleness

Physical properties: density; melting temperature

Thermal properties: expansivity; conductivity

Electrical and magnetic properties: conductivity; resistivity; permeability; permittivity

Effects of processing metals: recrystallisation temperature; grain structure eg hot working, cold working, grain growth; alloying elements in steel eg manganese, phosphorous, silicon, sulphur, chromium, nickel

Effects of processing polymers: process parameters eg moulding pressure and time, mould temperature, curing

Effects of processing ceramics: eg water content of clay, sintering pressing force, firing temperature

Effects of processing composites: fibres eg alignment to the direction of stress, ply direction; de-lamination; matrix/reinforcement ratio on tensile strength; particle reinforcement on cermets

Learning outcome

The learner will:

3 Understand the function of high voltage and low voltage switchgear

Assessment criteria

The learner can:

3.1 explain the purpose, operation and application of switchgear

3.2 explain the importance of switchgear to plant safety and the requirement to use specialist tools

3.3 identify hazards associated with maintenance activities on switchgear

3.4 identify switchgear component failure modes and causes

3.5 describe types and identification of HV and LV cabling

Range

Tools may include: lifting beams, Trolleys, Maintenance tools, Pumps, jacks, electrical test equipment which may include Meggers, Injection Test Sets, Partial Discharge Test Devices, Dielectric Strength Oil analysers

Hazards associated switchgear: Manual Handling Equipment's, COSHH requirements, PPE, Oil contaminants, Mechanical Forces (Risk) i.e. Spring Charge mechanism dangers, SF6 Gas leakage and the potential carcinogenic issues

Component failure modes and causes: Stiction' (Slow to trip switchgear), Partial Discharge (Arcing, ionisation), Oil dielectric strength failure, Low SF6 Gas (Sulphur Hexafluoride) Protection related failures (Buchholz, Overcurrent / Earth Fault, Over pressure, Lockout), Insulator Treeing & Tracking, low pressure, low vacuum. Main Contact / Rose and contact pitting Issues. Spring Charge and Auxiliary contact failures. Nanotechnology and identifying failure modes as a result of poor construction of conductive electrical components

Unit 314 Overhead line Infrastructure

Unit level:	Level 3
GLH:	60
Unit aim:	This unit provides the learner an opportunity to acquire knowledge of intermediate engineering mathematics

Learning outcome

The learner will:

1 Know the preparatory activities required for the construction of overhead line infrastructure

Assessment criteria

The learner can:

1.1 describe the legal and financial framework applicable to a project for a new section of railway infrastructure

1.2 describe the development process required for a new build or renewal within a railway environment

Range

Legal and financial framework: primary legislation eg Railways Act, regulations; funding of new railways eg Design, Build, Finance and Operate (DBFO), Private Finance Initiative (PFI); procedures to acquire land eg compulsory, compensatory

New build or renewal development process: route considerations eg need for service, number of tracks required, impact on the environment (noise, vibration, aesthetic, pollution, sustainability), stability, infrastructure integrity, associated structures (bridges, tunnels and level crossings); public consultation eg public enquiries, protests, environmental regulation, parliamentary approval; health, safety and welfare eg work force and public, legislation/regulations (Health and Safety at Work Act, Construction (Design and Maintenance) Regulations), method statements and safe methods of work, railway safety systems, industry standards (Network Rail, Railway Safety and Standards Board); contract administration eg legal process, selection of contract, contract conditions, methods of measurement

Learning outcome

The learner will:

2 Know the scope of earthwork activities that may be undertaken in association with overhead line infrastructure

Assessment criteria

The learner can:

2.1 describe methodology used for an overhead line earthworks project, including the plant and equipment required

2.2 describe the importance of foundations for the construction of overhead structures

Range

Earthworks project methodology: Use of Road/Rail Vehicles (RRV), setting out foundations, use of construction drawings, types of foundations (Planted with core former, Bolted base, Concrete cuboid, Gravity, Piled, Helical), Embankment construction eg suitable/unsuitable materials for fill, procedures and testing of soil properties as work proceeds; treatment of weak areas eg stabilisation, replacement and drainage techniques; ground water control eg methods of water table control (including vegetation), stability of slopes; forms of subsoil drainage eg patterns used, types of drainage (collector/carrier, open channel, use of interceptors, typical cross sections used); disposal of collected water eg open channel, soakaways, watercourses and drains via catchpits, discharge legislation (Environment Agency)

Learning outcome

The learner will:

3 Understand the forms of construction and materials used in overhead line infrastructure

Assessment criteria

The learner can:

3.1 explain the essential design principles for overhead line geometry

3.2 describe the construction methods for initial placement and subsequent maintenance activities to ensure overhead line position and geometry

3.3 describe the materials and quality control processes required to ensure the provision of suitable and sustainable overhead line construction material and waste material disposal

Range

Design principles: forms of construction eg light/heavy rail, specification selection, typical forms of track eg cross-sections of track types, formation specifications, sand blanket, geotextile; tunnels; walkways; track design considerations eg conventional passenger speed, enhanced passenger speed, transitions, curves, clearances, rolling stock; design standards eg Technical Specification for Interoperability, OHL Design Manual , OHL Construction Standards.

Construction methods: renewal methods and plant utilisation eg high output, conventional; methods of maintaining gauge clearance and track position (conventional and absolute track geometry); component fixity; stressing of rails; consideration of associated structures

Materials and quality control: sampling and testing of materials and component parts; product specification and approval processes; sustainable sourcing; waste material disposal eg ballast disposal, track recycling systems

Learning outcome

The learner will:

4 Understand overhead line maintenance processes used to identify and correct defects

Assessment criteria

The learner can:

4.1 describe the maintenance issues that need to be considered to determine rail infrastructure integrity

4.2 explain how rail infrastructure defects are identified and corrected

Range

Maintenance issues: fatigue defects eg rail defects; seasonal/environmental eg leaf fall, low/high temperature, snow, flooding; track component failure eg rail, sleeper, fastening; instability of sub-grade or ballast

Identification of rail infrastructure defects: inspection eg visual, vehicles; high speed testing/examination; review of outputs and application of maintenance standards; special inspections eg bridges, tunnels; rail defect classification

Corrective treatments: replacement of failed components; weld repair; grinding; leaf fall removal; remedial correction of defective ballast eg manual/mechanical methods to stabilise weak sub-grade

Unit 315 Overhead line technologies (construction)

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand basic surveying techniques

Assessment criteria

The learner can:

1.1 identify linear surveying terminology and equipment
1.2 identify levelling surveying terminology and equipment
1.3 carry out linear surveys using appropriate equipment to produce drawings
1.4 carry out levelling surveys using appropriate equipment to produce drawings
1.5 identify angular terminology and equipment

Range

Linear surveying terminology: framework; whole to part; well-conditioned; taping; horizontal and slope distances; chainage; running measurements; perpendicular offsets; tie lines; check lines

Linear surveying equipment: tapes; bands; rules; handheld lasers; ancillary equipment

Linear surveying drawings: internal or external survey plotted to scale

Levelling surveying terminology: back sight; intermediate sight; fore sight; reduced level; datum; Ordnance Survey Bench Mark; Temporary Bench Mark; height of collimation; rise and fall; fly levelling

Levelling surveying equipment: automatic levels; tilting levels; water levels; rotating lasers; barcode instruments

Levelling surveying drawings: spot heights on plans; sections

Angular Terminology: whole circle bearings; azimuth; horizontal angle; zenith angle; angles of inclination

Angular Equipment: optical square; theodolites

Learning outcome

The learner will:

2 Understand materials in the rail environment

Assessment criteria

The learner can:

2.1 describe mechanical, physical, thermal, electrical and magnetic properties of materials used in rail engineering

2.2 describe the effects of processing on the properties and behaviour of materials used in rail engineering

2.3 describe the principles of the modes of failure

Range

Mechanical properties: strength (tensile, shear, compressive); hardness; toughness; ductility; malleability; elasticity; brittleness

Physical properties: density; melting temperature

Thermal properties: expansivity; conductivity

Electrical and magnetic properties: conductivity; resistivity; permeability; permittivity

Effects of processing metals: recrystallisation temperature; grain structure eg hot working, cold working, grain growth; alloying elements in steel eg manganese, phosphorous, silicon, sulphur, chromium, nickel

Effects of processing thermosetting polymers: process parameters eg moulding pressure and time, mould temperature, curing

Effects of processing ceramics: eg water content of clay, sintering pressing force, firing temperature

Effects of processing composites: fibres eg alignment to the direction of stress, ply direction; de-lamination; matrix/reinforcement ratio on tensile strength; particle reinforcement on cermets

Learning outcome

The learner will:

3 Understand electrical systems used in the rail environment

Assessment criteria

The learner can:

3.1 describe the types and function of capacitors

3.2 explain the relationship between the voltage and current fo a charging and discharging capacitor

3.3 describe the characteristics of a magnetic field

3.4 describe the principles and applications of electromagnetic induction

3.5 determine the characteristics of sinusoidal AC waveform using single phase AC circuit theory

3.6 use test equipment to test AC circuits

Range

Capacitors: types (electrolytic, mica, plastic, paper, ceramic, fixed and variable capacitors); typical capacitance values and construction (plates, dielectric materials and strength, flux density, permittivity); function eg energy stored, circuits (series, parallel, combination); working voltage

Charging and discharging of a capacitor: measurement of voltage, current and time; tabulation of data and graphical representation of results; time constants

DC network that includes a capacitor: eg DC power source with two/three capacitors connected in series, DC power source

Magnetic field: magnetic field patterns eg flux, flux density (B), Magneto motive Force (MMF) and field strength (H), permeability, B/H curves and loops; ferromagnetic materials; reluctance; magnetic screening; hysteresis

Electromagnetic induction: principles eg induced Electromotive Force (EMF), eddy currents, self and mutual inductance; applications (electric motor/generator eg series and shunt motor/generator; transformer eg primary and secondary current and voltage ratios); application of Faraday's and Lenz's laws

Single phase AC circuit theory: waveform characteristics eg sinusoidal and non-sinusoidal waveforms, amplitude, period time, frequency, instantaneous, peak/peak-to-peak, Root Mean Square (RMS), average values, form factor; determination of values using phasor and algebraic representation of alternating quantities eg graphical and phasor addition of two sinusoidal voltages, reactance and impedance of pure R, L and C components AC circuit measurements: safe use of an oscilloscope eg setting, handling, health and safety; measurements (periodic time, frequency, amplitude, peak/peak-to-peak, RMS and average values); circuits eg half and full wave rectifier

Unit 316 Overhead line technologies (maintenance)

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand basic surveying techniques

Assessment criteria

The learner can:

1.1 identify linear surveying terminology and equipment
1.2 identify levelling surveying terminology and equipment
1.3 carry out linear surveys using appropriate equipment to produce drawings
1.4 carry out levelling surveys using appropriate equipment to produce drawings
1.5 identify angular terminology and equipment

Range

Linear surveying terminology: framework; whole to part; well-conditioned; taping; horizontal and slope distances; chainage; running measurements; perpendicular offsets; tie lines; check lines

Linear surveying equipment: tapes; bands; rules; handheld lasers; ancillary equipment

Linear surveying calculations: basic arithmetical operations

Linear surveying drawings: internal or external survey plotted to scale

Levelling surveying terminology: back sight; intermediate sight; fore sight; reduced level; datum; Ordnance Survey Bench Mark; Temporary Bench Mark; height of collimation; rise and fall; fly levelling

Levelling surveying equipment: automatic levels; tilting levels; water levels; rotating lasers; barcode instruments

Levelling surveying calculations: basic arithmetical operations, simple trigonometry

Levelling surveying drawings: spot heights on plans; sections

Angular Terminology and equipment: whole circle bearings; azimuth; horizontal angle; zenith angle; angles of inclination, optical square; theodolites

Learning outcome

The learner will:

2 Understand materials in the rail environment

Assessment criteria

The learner can:

2.1 describe mechanical, physical, thermal, electric and magnetic properties of materials used in rail engineering

2.2 describe the effects of processing on the properties and behaviour of materials used in rail engineering

2.3 describe the principles of the modes of failure

Range

Mechanical properties: strength (tensile, shear, compressive); hardness; toughness; ductility; malleability; elasticity; brittleness

Physical properties: density; melting temperature

Thermal properties: expansivity; conductivity

Electrical and magnetic properties: conductivity; resistivity; permeability; permittivity

Effects of processing metals: recrystallisation temperature; grain structure eg hot working, cold working, grain growth; alloying elements in steel eg manganese, phosphorous, silicon, sulphur, chromium, nickel

Effects of processing thermosetting polymers: process parameters eg moulding pressure and time, mould temperature, curing

Effects of processing ceramics: eg water content of clay, sintering pressing force, firing temperature

Effects of processing composites: fibres eg alignment to the direction of stress, ply direction; de-lamination; matrix/reinforcement ratio on tensile strength; particle reinforcement on cermets

Learning outcome

The learner will:

3 Understand principles of maintaining overhead lines

Assessment criteria

The learner can:

3.1 calculate the magnitude, direction and position of the line of action of the resultant and equilibrant of a non-concurrent coplanar force system containing a minimum of four forces acting in different directions

3.2 calculate the support reactions of a simply supported beam carrying at least two concentrated loads and a uniformly distributed load

3.3 calculate the induced direct stress, strain and dimensional change in a component subjected to a direct uniaxial loading and the shear stress and strain in a component subjected to shear loading

Range

Non-concurrent coplanar force systems: graphical representation e.g. space and free body diagrams; resolution of forces in perpendicular directions e.g. $Fx = F\cos\theta$, $Fy = F\sin\theta$; vector addition of forces, resultant, equilibrant, line of action; conditions for static equilibrium ($\Sigma Fx = 0$, $\Sigma Fy = 0$, $\Sigma M = 0$)

Simply supported beams: conditions for static equilibrium; loading (concentrated loads, uniformly distributed loads, support reactions)

Loaded components: elastic constants (modulus of elasticity, shear modulus); loading (uniaxial loading, shear loading); effects e.g. direct stress and strain including dimensional change, shear stress and strain, factor of safety

Kinetic parameters: e.g. displacement (s), initial velocity (u), final velocity (v), uniform linear acceleration (a)

Kinetic principles: equations for linear motion with uniform acceleration ($v = u + at$, $s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$, $s = \frac{1}{2}(u + v)t$)

Unit 317 Function and characteristics of railway signaling systems

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand the role of rail signaling within the railway system

Assessment criteria

The learner can:

1.1 explain the purpose and scope of a signaling system within the rail system

1.2 explain the man-machine interfaces, their problems and how they are addressed

Range

Purpose and scope of a signaling system: detection; separation of trains; use of points; route-setting; signal formation and permanent way eg interface between ballast, track, traction systems (electrification – catenary, third rail), train braking systems; signaling and control methods eg staff and competence, rules and regulations (control of train movements), capacity planning (headway, basis of timetable); signaling and external interfaces eg level crossings, other infrastructure owners

Man-machine interface: the driver and signaler interface; warning and advisory systems eg Advanced Warning System (AWS), Train Protection Warning System (TPWS), Automatic Train Protection (ATP), accidents and preventive measures, automation

Learning outcome

The learner will:

2 Understand the principles of safety and high integrity systems as applied to a railway signaling system

Assessment criteria

The learner can:

2.1 explain the principles of high integrity engineering with reference to the components of a signaling system

Range

High-integrity systems: principles eg fail-safe, wrong-side, right-side, failures, resilience, graceful degradation; components of signaling system eg control circuitry (logic control and computing systems), lamps/bulbs, relays

Application of principles throughout lifecycle: Reliability, Availability, Maintainability and Safety (RAMS); concept of redundancy; inherent safety characteristics; independent checks

Learning outcome

The learner will:

3 Know the function and characteristics of line-side signaling elements

Assessment criteria

The learner can:

3.1 describe the application of principles throughout the signaling lifecycle
3.2 explain the function of elements of a signaling system
3.3 explain the consequences of failure of a signaling system and associated risk mitigation
3.4 describe the main line-side elements of a typical railway signaling system

Range

Function of elements: relationship between points, signals, train detection, communications and power; interfacing with signaler and driver

Consequences of failure/incorrect commissioning: concepts of protected and unprotected failures; concept of As Low As Reasonably Practicable (ALARP)

Risks and mitigation: design and construction features; testing and commissioning; preventive maintenance

Main line-side elements: eg control cabinets, signal posts/gantries, ground signals, route displays (feathers, theatre boxes), power systems, illumination systems/lamps

Learning outcome

The learner will:

4 Understand information associated with signaling systems

Assessment criteria

The learner can:

4.1 describe how information is obtained and the importance of documentation control
4.2 describe signaling abbreviations, symbols and definitions

Range

Obtaining information: government sources eg Her Majesty's Railway Inspectorate (HMRI), infrastructure controller (Network Rail national records group); contractors (manufacturers' operations manuals); professional bodies eg Institution of Engineering and Technology (IET), Institution of Railway Signal Engineers (IRSE); role of IRSE licensing; Rail Safety and Standards Board (RSSB) Railway Group Standards(RGSs); company standards and instructions eg specifications, drawings and records

Document control: categories of documents eg signaling plans, content identification; issue and distribution control, authorisations and signatures; correction systems; feedback from site after alterations; change control eg asset registers, management of versions (especially software), compatibility and obsolescence effect

Signaling abbreviations, symbols and definitions: abbreviations eg Advanced Warning System (AWS), Solid State Interlocking (SSI); symbols eg semaphore signal, point machine, multiple aspect signal, ground signal; definitions eg vital, non-vital

Unit 318 Signaling technologies

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand the function and operation of diodes, transistors and logic gates

Assessment criteria

The learner can:

1.1 explain the purpose of different diodes in different electronic circuit applications

1.2 explain the operation of different types of transistor in analogue and digital circuits

1.3 explain the operation of logic gates with appropriate gate symbols, truth tables and Boolean expressions

Range

Diodes: types eg Zener, light emitting diode (LED), PN-junction; circuit applications eg voltage stabiliser, indicator light, half-wave rectifier

Transistors: types eg NPN, PNP or Field-Effect Transistor (FET); analogue circuit (single-stage amplifier); digital circuit eg comparator, transistor as a switch (automatic night light); operation eg analogue (voltage gain, phase inversion), digital (set-point of operation); function of components in circuits

Logic gates: types of gates eg AND, OR, NOT, NAND, NOR, XOR; gate symbols eg British Standards (BS), International Electrotechnical Commission (IEC), American National Standards Institute (ANSI); truth tables; Boolean expressions eg A+B, $\bar{A}$, A•B

Learning outcome

The learner will:

2 Be able to build and test operational amplifier-based analogue circuits

Assessment criteria

The learner can:

2.1 build and test analogue circuits using operational amplifiers

Range

Building analogue circuits: method of construction eg prototype/bread-board, printed circuit, strip-board; types of circuits eg oscillator, filter circuit, comparator circuit, inverting and/or non-inverting amplifier

Testing analogue circuits: performance against given design requirement; recording actual input and output voltages (tabulating data, plotting graph of results); circuit measurements eg measurement of resonant frequency, cut-off frequency, switching point, gain at mid-frequency, bandwidth

Learning outcome

The learner will:

3 Be able to build and test combinational and sequential logic circuits

Assessment criteria

The learner can:

3.1 build and test combinational logic circuits that have three input variables

3.2 build and test sequential circuits using integrated

Range

Building combinational and sequential logic circuits: types of combinational circuit eg at least three gates and three input variables; types of sequential circuit eg R-S bi-stables, JK bi-stable, 3-stage counter, 3-stage shift-register based on JK or D-type bi-stables; types of logic family eg Transistor-Transistor Logic (TTL) and Complementary Metal Oxide Semiconductor (CMOS); characteristics of chips eg supply voltage, input and output operating voltages, input and output impedance, propagation delay, power

Testing of logic circuits: records of performance against given design requirement; input and output states; use of truth tables; use of test equipment eg logic probe, signature analyser

Minimisation of logic circuits: eg use of De-Morgan's theorem; Karnaugh maps

Learning outcome

The learner will:

4 Know about system monitoring and reliability

Assessment criteria

The learner can:

4.1 describe condition monitoring methods and techniques

4.2 calculate failure rates for components and equipment

4.3 describe the factors affecting reliability engineering systems

Range

Monitoring terminology: condition monitoring methods eg offline portable monitoring, sampled monitoring, continuous monitoring, protection monitoring, human sensory monitoring; monitoring techniques eg vibration analysis, temperature analysis, flow analysis, particle analysis, crack detection, leak detection, pressure analysis, voltage/current analysis, thickness analysis, oil analysis, corrosion detection, environmental pollutant analysis

Failure and reliability: calculations concerning failure eg degrees and causes of failure, failure rate, failure modes, functional failure, primary and secondary functions, Mean Time Between Failures (MTBF), reliability; factors affecting reliability eg design, operation, environment and manufacture, reduction in system/device failure eg routine servicing, adjustments; data eg defects examination, Statistical Process Control (SPC), quality

Unit 319 Telecommunication technologies

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Know the main elements of data communications system

Assessment criteria

The learner can:

1.1 identify and explain types of communication devices

1.2 explain the principles of signal theory

Range

Communication devices: wired devices eg Data Terminal Equipment (DTE), Data Circuit-terminating Equipment (DCE); wireless devices eg Third Generation (3G) cellular phone, wireless Personal Data Assistant (PDA), wireless laptop

Signal theory: digital signaling methods; representing data electronically (bits, bytes, packet structures); synchronous and asynchronous transmission; error correction and detection; effect of bandwidth limitation and noise; channel types eg telephone, High Frequency (HF) radio, microwave, satellite; other issues eg bandwidth, data compression

Learning outcome

The learner will:

2 Understand the communication principles of computer networks

Assessment criteria

The learner can:

2.1 identify and describe the roles of network components and how they are interconnected

2.2 describe the features of networks and the communication services they offer

2.3 describe different methods of electronic communication and transmission media used

Range

Features of networks: types eg LAN,WAN, wireless; network topologies eg star; mesh; bus; tree (or hierarchical);ring ; network services eg packet switched, ISDN, multiplexed, ATM,WAP, broadband; network software eg network operating system; network connection software; access methods eg CSMA/CD, CSMA/CA, token passing

Network components: servers; workstation; network cards eg Ethernet, wireless, token ring

Interconnection devices: eg hubs; switches; routers; repeaters; bridges; gateways, wireless devices

Learning outcome

The learner will:

3 Understand transmission protocols and models

Assessment criteria

The learner can:

3.1 describe communication protocols used and explain why they are important

3.2 describe communication models used and explain why they are important

Range

Protocols: eg Bluetooth, Wifi, IrDa, cellular radio; examples eg GSM/UMTS, WAP, WML; 802.11x standards, TCP/IP; wireless security protocols eg WEP TCP/IP model: levels and relationship with connection devices

Model: example eg Open System Interconnection (OSI) model: levels and relationship with connection devices

Learning outcome

The learner will:

4 Understand internet communications

Assessment criteria

The learner can:

4.1 describe the nature of internet communication and the associated system requirements

Range

Internet communication: terminology eg HTTP, HTTPS, FTP, SMTP; uniform resource locator; worldwide web; other; eg blogs, wikis, video conferencing, vlogs

System requirements: hardware and software system requirements eg for wired or mobile systems; communication services eg email, video, internet; software; configuration

Unit 320 Telecommunication principles

Unit level:	Level 3
GLH:	60

Learning outcome

The learner will:

1 Understand telecommunication circuits and transmission lines

Assessment criteria

The learner can:

1.1 describe the properties of circuits with reactive and resistive components

1.2 describe the characteristics of transmission lines with reference to equivalent circuit models

1.3 describe the properties of digital signals and the impairments that affect them

Range

Circuit properties: behaviour of inductance, capacitance and resistance in Alternating Current (AC) circuits; concept of reactance; concept of impedance in terms of resistive and reactive components; characteristics of parallel and serial resonant circuits; statement of the formula for determining resonant frequency in terms of resistance, capacitance and inductance

Characteristics of transmission lines: equivalent circuit model of a transmission line in terms of resistance, capacitance and inductance; concept of characteristic impedance; conditions for maximum power transfer between a source and a load; typical values of characteristic impedance for various types of cable eg co-axial cable, twisted pairs; definition of bandwidth of a line in terms of the frequency range between half power points

Digital signals: representation of binary information using Non-Return to Zero (NRZ) and Return to Zero (RZ) waveforms; advantage of RZ in terms of extracting clocking information; digital signal impairments(delay, jitter, binary errors); effects of delay, limited bandwidth and jitter on the extraction of binary information from a digital signal; definition of bit rate and Bit Error Rate (BER)

Learning outcome

The learner will:

2 Understand the principles of frequency modulation and multiplexing

Assessment criteria

The learner can:

2.1 describe signal modulation techniques and the properties of a modulated signal

2.2 describe the principles and benefits of analogue to digital conversion

2.3 describe the principles and benefits of frequency and time division multiplexing

Range

Modulation techniques: reasons for modulation of electrical signals; concepts of modulating signal and carrier; principles of Amplitude Modulation (AM), Frequency Modulation (FM) and Phase Modulation (PM) in terms of the effect of the modulating signal on the properties of the carrier eg phase, amplitude, frequency; properties of AM, FM and PM signals eg bandwidth requirement, relative noise immunity; transmission of binary code using on—off keying

Analogue to digital conversion: principles of Pulse Amplitude Modulation (PAM) with reference to sampling amplitude levels; principles of Pulse Code Modulation (PCM) in terms of converting sampled levels into binary code; function of an encoder/decoder combination (codec) for transmission of speech, transmission of video; benefits eg higher noise immunity, enabling of bandwidth compression techniques

Frequency and time division multiplexing: principles eg transmitting traffic from Various sources at different frequencies, reference to transmission timeslots; benefits of multiplexing eg reduction in number of links in a network, reduction in operating and equipment costs

Learning outcome

The learner will:

3 Be able to carry out measurements on telecommunications electrical circuits

Assessment criteria

The learner can:

3.1 make measurements on telecommunication electrical circuits

Range

Measurements on electrical circuits: use of test equipment eg oscilloscope, function generator , frequency meter, power meter; measurements (resonant frequency, signal phase shift, bandwidth, pulse shape, signal power);recording and presenting test results eg tabulation of data, graphical representation (line chart, bar chart, pie chart, column chart), paper- or computer-based methods

Learning outcome

The learner will:

4 Understand the applications of electromagnetic theory in telecommunications.

Assessment criteria

The learner can:

4.1 describe the characteristics and application of frequency bands in the electromagnetic spectrum

4.2 explain how transformers and other telecommunication devices make use of the principles of electromagnetism.

Range

Electro-magnetic spectrum frequency bands: applications from Near Infrared (NIR) band to Low Frequency (LF) band eg mobile telephony, optical fibre transmission, satellite communications, broadcast radio and television, microwave radio links; propagation characteristics eg line of sight, groundwave, ionospheric refraction, reflection

Applications of electromagnetism: principles of operation eg role of electromagnetism, main components; relevance of turns ratio; efficiency of a transformer in terms of relationship between input power, output power and losses (eddy currents, hysteresis); other telecommunications applications eg microphone, loudspeaker