

IRSE Professional Examination

SYLLABUS

AUTHORISATION AND REVISIONS

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AIMS AND OBJECTIVES OF THE EXAMINATION SYLLABUS

Notes to Students

This syllabus is intended to give a detailed description of the topics that may be covered in the IRSE examination, indicating the breadth and the depth of knowledge of topics and skills required. The student is expected to answer in the context of a type of railway and organisation with which they are familiar. The questions are designed to be answered using the principles and practices of any railway organisation, whether heavy rail or rapid transit and wherever in the world it operates.

The syllabus for each module sets out the specific aims and learning objectives. The notes on this page should be used as a general guide to those aims and objectives when reading the syllabus:

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This gives a general overview of what is required for the module and contextualises the Learning Objectives.

LEARNING OBJECTIVES

The learning objectives in each module have been grouped in three sections, the purpose of each section being as follows:

To understand and explain:

This is intended to indicate the depth and breadth of the knowledge required to underpin the following skills. You may be asked to describe or explain topics under this heading in the examination.

To be able to:

A major objective of the examinations is to test the student's operational competence as well as underpinning knowledge. This section indicates the key skills that are expected of the professional railway signalling or communications engineer within the context of the module. You will be expected to demonstrate that you can apply these skills through worked examples, and explain your reasoning at each stage.

Related Content (further reading):

Topics within each module are rarely discrete but are interdependent on an understanding of topics that may be dealt with in more detail in other modules.

Other topics, not specifically covered by the other modules but relevant to the subject matter, will also be stated here.

Whilst the topics described in this section are not intended to be core subjects for the module, an understanding of them within the context of the module will help to demonstrate a wider understanding of the subject matter, and to give a more professional answer.

Module 1

Safety of Railway Signalling and Communications

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The aim of this module is to assess the students' understanding of the principles and practices associated with the safety of train control and communications systems, and of the factors that are relevant in ensuring the safety of those systems. It also includes the competence of people who work on such systems.

LEARNING OBJECTIVES

To understand and explain:

- a) The legal framework, requirements and standards governing railway safety in force in the student's own country
- b) The principles of safety engineering for the whole life-cycle of a train control or communications system (from concept through to decommissioning)
- c) Methods of demonstrating and assuring the safety and security of train control and communications systems
- d) Safety management techniques, including quantified and qualitative risk assessment
- e) Methods for specifying and demonstrating the achievement of appropriate levels of safety
- f) Design principles for train control / communications systems to minimise the risk of failure (including "wrongside" failure)
- g) The use/design of protection measures within train control / communications systems to guard against human error
- h) Managing the risks associated with alterations to existing train control / communications systems
- i) The interdependency between operating rules and the design of train control / communications systems to ensure the safe working of the railway
- j) How to ensure safe railway operation during periods of failure of train control / communication systems
- k) The human, economic, technological and environmental factors that affect the safety of train control / communications through the whole system life-cycle
- l) The application of quality control and quality management techniques to train control and communications systems
- m) Managing the competence of those involved in the design, construction, operation and maintenance of train control / communications systems
- n) The broader obligations of engineers to society in respect of safety, efficient and economical use of resources, environmental management etc
- o) Accident investigation processes and the management of measures to prevent recurrence

To be able to:

- a) Compile a safety plan for a relevant activity
- b) Apply techniques for hazard identification, risk assessment and mitigation
- c) Define the processes for ensuring safety in the specification, design (data preparation, circuit design, etc), verification, testing and commissioning (validation) of train control / communications systems
- d) Manage staff competence (select/train/resource/authorise/motivate/monitor)

Related content:

- Prescriptive and performance based specifications
- Signalling / Telecommunications Principles
- Interactions and interfaces with rolling stock, other infrastructure etc.

Module 2

Signalling the Layout

AIM

The aim of this module is to assess the students' ability to signal a layout for a variety of different operational requirements, train control systems and equipment, in a cost effective manner, taking into account the constraints of the layout and safety requirements. Students may choose between a mainline plan or a rapid transit plan, to best suit their knowledge and experience.

LEARNING OBJECTIVES

To understand and demonstrate:

- a) The relationship between the provision/spacing of signals and:
 - traffic operating patterns and traffic mix
 - rolling stock characteristics (acceleration, maximum speed and braking characteristics),
 - infrastructure characteristics (track layout, speed limits, gradients) and the spacing of signals.
- b) The calculation of time, distance and speed curves
- c) Headway requirements
- d) What information must be generated or provided before and in conjunction with signalling a layout in order that operators can assess whether it meets their requirements, and in order for designers to be able to generate detailed safe designs.

To be able to:

- a) Demonstrate mathematically or graphically the signalling calculations necessary to meet a given traffic operating pattern and mix of traffic.
- b) Interpret signalling principles and operational requirements/rules, in order to show upon a given track plan the details of the signalling required for the safe and efficient movement of trains under normal and, where applicable, degraded modes of operation.
- c) Mark upon that plan the additional information required by designers (eg the geographical limits of train detection, the normal lie of points, the allocation of equipment identities)
- d) Identify safety risks associated with the signalling arrangements, and potential mitigating measures

Related content:

- Signalling principles
- Signalling equipment and their principles of operation (signals, train detection equipment, points, level crossings etc)
- Aspect sequences
- Systems for protecting against driver error (passing signals at "danger", overspeeding), their uses and limitations
- Cost implications of choice of signalling arrangements
- Implications for reliability, availability, maintainability, recovery and people of choice of signalling system

Module 3

Signalling Principles

AIM

The aim of this module is to assess the students' understanding of the principles of operation of signalling systems and sub-systems, and their ability to apply their knowledge to develop and design signalling applications that are safe, fit for purpose and cost effective.

LEARNING OBJECTIVES

To understand and explain:

- a) Fundamental requirements for train control systems
- b) Principles of route and speed signalling
- c) Principles of absolute block and permissive working
- d) Principles of control of single line railways
- e) Principles of moving block
- f) Principles of signalling interlocking systems
- g) Principles of train detection systems
- h) Principles of cab signalling systems
- i) Principles of transmission/radio based signalling
- j) Principles of systems for protecting against driver error (passing signals at "danger", over-speeding), including automatic train protection systems (ATP)
- k) Principles of automatic train operation (ATO)
- l) The role of Control Centres
- m) Principles of different types of railway crossings (grade/level/pedestrian crossings etc)
- n) How levels of safety and availability are apportioned within the parts of a train control system so as to ensure an adequate overall level of safety (control centre, interlocking, power systems, communications systems, trackside objects etc)
- o) Principles of safe operation during periods of failure of the train control system
- p) General principles of safety in relation to the application of signalling principles
- q) How train control systems are tested to ensure they conform to signalling principles
- r) The impact of the design of other parts of railway infrastructure on the application of signalling principles and layouts (electrification systems, track, stations etc)

To be able to:

- a) Prepare interlocking and control tables for given layouts (or parts), or their equivalent where it is not local practice to provide them
- b) Apply signalling principles in conjunction with specific operating requirements and track layouts in a safe and cost effective manner
- c) Prepare an aspect sequence or equivalent chart for a given signalling arrangement
- d) Prepare factory and site acceptance test plans to demonstrate that a train control system (or a part of it) conforms to the relevant signalling principles and operational requirements

Related content:

- Factors affecting the safety, availability, reliability and maintainability of equipment and systems
- Rules of operation for the safe working of the railway, including working under degraded conditions
- Human factors affecting the design of the signalling system, and protection measures to guard against human error (eg by drivers, signallers and maintainers)
- Cost implications of the choice of signalling arrangements

Module 4

Communications Principles

AIM

The aim of this module is to assess the students' understanding of the principles of operation of railway communication systems and sub-systems, and their ability to apply their knowledge to develop and design communications applications that are safe, fit for purpose and cost effective.

LEARNING OBJECTIVES

To understand and explain:

- a) Radio (RF), Voice and Data transmission theory, modulation types, and security
- b) Transmission coding theory and methods, error detection and recovery, spread spectrum techniques
- c) Transmission systems, networks and technologies, PDH, SDH, Ethernet, DWDM, CWDM
- d) Telephone systems and networks, including railway operational, business and VoIP systems
- e) Principles and protocols of TCP/IP
- f) Network architectures to achieve specified performance and resilience, from TCP/IP to legacy networks
- g) Radio propagation: point to point and mobile, frequency allocation and regulation, aerials and mast site criteria, surveys, tunnel solutions (for instance RF-over-fibre, radiating cables), multi-user distributed systems
- h) Mobile radio standards including GSM-R (including GPRS) LTE, TETRA, FDMA and TDMA, wireless LAN
- i) Transmission systems (analogue and digital); copper, fibre optic satellite and radio-based (including microwave)
- j) Television: closed circuit, security, data recording, transmission and storage techniques, remote and local control, image recognition techniques
- k) Cable/cabling principles, standards, usages, coaxial (video, RF and data), copper, optical fibre, structured cabling systems (eg ANSI/TIA-568-C, ISO/IEC 11801)
- l) Satellite-based positioning and communication systems
- m) Electromagnetic compatibility (EMC) and electromagnetic interference (EMI); theory, immunisation, legal requirements, effects and causes (including inter-modulation, induced voltages)
- n) Earthing, bonding, lightning and surge protection systems
- o) Network planning, voice, data and radio
- p) Network security, vulnerabilities and resilience to single point failure

To be able to:

- a) Apply communications principles to specific railway applications in a safe and cost effective manner
- b) Develop methods of proving that specific applications meet the required performance specification
- c) Describe the techniques for securing open and closed communication systems from unauthorised access or interference.
- d) Identify potential system compatibility and integration risks, impact analysis, and mitigation measures (for connecting new, legacy and third party provided systems)

Related content:

- National and international regulations: ITU, statutory and others
- Railway operating rules relevant to communications, including working under degraded conditions.

Module 5

Signalling and Control Equipment: Applications Engineering

AIM

The aim of this module is to assess the students' understanding of the factors to be considered when using items of signalling equipment as part of a signalling system, at all stages in the life-cycle from specification to replacement / decommissioning.

LEARNING OBJECTIVES

To understand and explain:

- a) The properties, applications and limitations of the following types of systems and equipment:
- Cables and cabling systems
 - Power supplies
 - Train detection systems and equipment
 - Personnel protection systems
 - Hot axle box / other train defect detectors
 - Vehicular level crossings and pedestrian crossing protection)
 - Remote control and indication systems, and condition monitoring systems
 - Lightning protection, earthing, traction and bonding systems
 - Test equipment and gauges
 - Signals
 - Relays
 - Interlockings
 - Automatic Train Operation
 - Train protection and warning systems, including ETCS
 - Automatic Train Supervision and scheduling
 - Single line working systems
 - Cab signalling systems
 - Data and incident recorders
- b) Positioning of equipment for operational requirements, constructability, safe operation and maintainability (including specifically the positioning and visibility of lineside signals)
- c) Environmental factors affecting the choice, use and physical location of equipment, including extreme weather environments, tunnel and underground environments etc
- d) Principles of equipment design and selection to minimise the risk of human error by operators, users and maintainers
- e) Use and limitations of equipment for monitoring other aspects of railway performance (eg train detection systems for monitoring broken rails, train integrity systems)
- f) Information required from train control systems and equipment for monitoring systems, the management of maintenance, and customer information applications
- g) Train, electrification and other interference characteristics, immunisation, electromagnetic compatibility
- h) Methods for testing equipment
- i) Principles and purposes of equipment/product approval
- j) Information, diagnostic tools and other resources required by maintainers.

To be able to:

- a) Prepare a functional specification for items of signalling equipment
- b) Select signalling equipment for specific applications to meet requirements for safety, reliability, availability, maintainability, environmental protection and cost-effectiveness
- c) Prepare an analysis of the safety and reliability of an item of equipment, including the production of fault trees (or similar, eg failure modes and effects analysis) for given equipment and sub-systems
- d) Prepare a testing strategy for a signalling system
- e) Define requirements and arrangements for effective handover of equipment and subsystems for operations and maintenance purposes
- f) Specify arrangements to provide for the continued safe and reliable operation of given equipment and subsystems at all stages of the lifecycle

Related content:

- Equipment failure investigation
- Type approval and assessment requirements
- Operational requirements
- Equipment servicing, maintenance and replacement
- Ergonomics, human factors and human error
- Safety arguments / analysis
- Specifications
- Impact of equipment response times
- Installation
- Whole Life Costs

Module 6

Communications Equipment: Applications Engineering

AIM

The aim of this module is to assess the students' understanding of the factors to be considered when using items of communications equipment as part of a railway communications system, at all stages in the life-cycle from specification to replacement / decommissioning.

LEARNING OBJECTIVES

To understand and explain:

- a) The properties, applications and limitations of the following types of equipment:
- Telephone systems including operational and business telephone systems
 - Cables/cabling system selection for RF, voice and data applications (both within buildings and over longer distances)
 - Radio systems for railway operations; driver only operation, track to train systems, point to point systems, token systems
 - Safety critical communications, land-based and mobile, including use of public networks;
 - Wireless (wi-fi and LAN) networks for operations, business and passenger purposes
 - Public Address (station and long line)
 - Customer information Systems; real time and interactive systems
 - Geo-positioning technologies (GPS, GLONASS, Galileo)
 - Electrification power control: transmission and security
 - Clock and timing synchronisation systems
 - CCTV systems for operational purposes
 - Specific requirements for communications systems in underground and sub-surface railways
 - SCADA systems
 - Earthing, lightning and surge protection systems
 - Power supplies: main, standby, UPS, batteries
 - Network management, intelligent infrastructure and remote condition monitoring
 - Video, voice, data recording systems – capacity, secure storage, information retrieval
- b) Testing and commissioning, roles and responsibilities, testing strategies and plans, risk management, competence and independence from design

To be able to:

- a) Prepare a functional specification for an item of telecommunications equipment
- b) Select telecommunications equipment for specific applications to meet requirements for safety, reliability, environmental protection and cost-effectiveness
- c) Prepare an analysis for the safety and reliability of the equipment, including the production of fault trees (or similar, eg failure modes and effects analysis) for given equipment and sub-systems
- d) Prepare a testing strategy for a safety related communications system
- e) Plan the effective handover of equipment and subsystems for operations and maintenance purposes
- f) Specify arrangements to provide for the continued safe and reliable operation of given equipment and subsystems at all stages of the lifecycle

Related content:

- Safety cases
- Specifications
- Type approval and assessment requirements
- Quality of service
- Impact of equipment response times
- Operational requirements
- Servicing, maintenance and replacement
- Ergonomics, disability and discrimination considerations
- Whole life costs

Module 7

Systems, Management and Engineering

AIM

The aim of this module is to assess the students' understanding of systems engineering principles and practices as applicable to railway train control and communications systems.

LEARNING OBJECTIVE

To understand and explain:

- a) The application of systems engineering to railways (including train control and communications systems in particular)
- b) Stages of a train control or communications project and the use of stage-gates to manage progress
- c) The application of the "V" life-cycle to the development, design, verification, validation and integration of train control / communications systems
- d) The advantages and disadvantages of automating the design and testing of train control systems
- e) Methods for specifying and demonstrating the achievement of appropriate levels of reliability, availability, maintainability and safety
- f) System architectures, boundaries, and the apportionment of functions to sub-systems
- g) System requirements management - definition, analysis and traceability
- h) Specification of interfaces between sub-systems
- i) Interactions, interfaces and compatibility with other railway systems
- j) Systems integration
- k) Migration strategies from old to new systems: requirements and techniques
- l) Protection of equipment and systems against accidental and deliberate damage that could compromise safety and performance (for example, physical damage of equipment; electrically induced damage to electronic systems; cyber threats to software-based systems)
- m) Human performance and human-machine interface issues
- n) Automating the operation of train control and traffic management systems
- o) Operational integration, including staff training, maintenance readiness and the development of processes and rules
- p) Designing for maintainability
- q) Design and operational considerations for failure conditions and restoration of normal service
- r) Environmental factors affecting systems
- s) Environmental impact of systems, equipment and engineering construction activities
- t) Obsolescence management
- u) Configuration management and change control
- v) Whole-life cost/benefits analysis
- w) Use of modelling and simulation in systems development
- x) Use of DRACAS and FRACAS

To be able to:

- a) Prepare a system specification and apportion requirements to different sub-systems
- b) Produce a Systems Engineering Management Plan
- c) Configure systems to achieve safety, reliability and cost-effectiveness
- d) Calculate the reliability and availability of a system
- e) Produce a systems integration test plan

Related Content:

- Management and control procedures during the design and development phases of a project
- Control systems theory
- The advantages and limitations of new technologies
- Human factors and human error
- Hazard and risk assessment, identification and analysis techniques
- Relevant standards