Aim of Module 3 Study Guide

The aim of this module is to assess

- the student's 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.

The aim of this study guide is to assist candidates with their preparation for the Institution of Railway Signal Engineers (IRSE) Module 3 Exam paper. It is not intended to be a comprehensive study course, but expects some railway domain knowledge. As far as possible, the guide is written to take into account that candidates for this module may not have significant experience in a signalling design role.

Issue Status

<table>
<thead>
<tr>
<th>Date</th>
<th>Issue No</th>
<th>Amendments</th>
<th>Authorised by E&amp;PD Committee dated</th>
</tr>
</thead>
<tbody>
<tr>
<td>05/2016</td>
<td>1.0</td>
<td>New issue in revised format</td>
<td>9 April 2016</td>
</tr>
<tr>
<td>01/2017</td>
<td>1.1</td>
<td>Minor updates</td>
<td>24 January 2017</td>
</tr>
</tbody>
</table>
1 Introduction

1.1 Module context
The IRSE exam tests candidates' understanding of signalling principles. Candidates are expected to understand the underlying reasons for the ways they design, install and maintain signalling. Their understanding should go beyond written standards and procedures to the reasoning and considerations that led to a particular approach being adopted. Some railways/companies have created detailed design rules and processes to be followed which improves the quality of design and allows less skilled staff to design reliably. Examination candidates must demonstrate they understand the rationale behind the design rules, and not just that they can follow processes defined by others.

IRSE Exam modules 2 and 3 cover the conceptual design of signalling systems to meet the functional and performance needs of a railway system. Module 5 covers the design of signalling equipment and its detailed application. Candidates who have studied or who are studying other IRSE Exam modules will find a degree of overlap, especially between modules 2, 3, and 5.

Module 3 does not test whether you know the principles for the railway you are familiar with (although that helps) but explores whether you can justify the principles, identify the potential weaknesses in them and apply logic and learning from other spheres. As a professional engineer you are likely to be asked to assess a new product or system, this requires you to think laterally and logically to identify which principles should be applied, and, where they do not exist, how you would generate new rules.

1.2 Study resources

1.2.1 Reading list
The reading list for this and the other IRSE Exam modules are available separately. There is some overlap in the reading lists between the different modules. Candidates should not restrict themselves to the publications listed since they are expected to be aware of recent developments. Questions are often topical in nature, so reading IRSE News, attending IRSE events, and pertinent IET (Institution of Engineering and Technology) events can be helpful preparation (and similar activities for other organisations within the industry).

1.2.2 Past papers and sample answers
Complete copies of past exam papers are provided by the IRSE for candidates to use in their preparation. Some sample answers are also provided along with examiners' comments. Example questions are also included in this study guide to show how each topic relates to the exam.

Exam questions frequently cover more than one topic and therefore may be included in more than one chapter of this study guide.

1.2.3 Study guide
While the desire is to make this study guide generic (i.e. applying to most railways worldwide), the primary author's experience is limited to recent UK mainline railways. Inevitably therefore, the content is biased. Offers to assist in correcting this would be most welcome. Where specific examples are used, from UK or another national practice, they are highlighted with a light grey background. Candidates from other countries and other railways may find it helpful to read this material and understand the principles they illustrate.

The study guide is intended to direct candidates' study, not to be a complete and comprehensive manual or textbook. It should be used alongside other resources.

1.3 Feedback
Suggestions to improve this study guide are most welcome, so if you are able to help improve this guide then please see the feedback form at the end of this document.
## 2 Table of Contents

1.1 Module context ................................................................. 2
1.2 Study resources............................................................... 2
1.3 Feedback........................................................................... 2

2 Table of Contents.................................................................. 3

3 Practical Guidance for the Exam.............................................. 6
  3.1 General information and instructions............................... 6
  3.2 Control tables questions.................................................. 6
  3.3 Aspect sequence questions.............................................. 6
  3.4 Written questions........................................................... 6

4 Fundamental Requirements of Train Control.......................... 8
  4.1 Operational requirements................................................ 8
  4.2 Core functional safety requirements................................ 8
  4.3 Essential supporting safety requirements........................ 8
  4.4 Past exam questions....................................................... 9

5 Types of Train Control........................................................... 10
  5.1 On-sight train control....................................................... 10
  5.2 Time interval working..................................................... 10
  5.3 Absolute block working................................................... 10
  5.4 Track circuit block working (Multiple Aspect Signalling [MAS]) 10
  5.6 Communication Based Train Control (CBTC).................... 13
  5.7 Moving block working..................................................... 13
  5.8 European Train Control System (ETCS)............................ 13
  5.9 Past exam questions....................................................... 14

6 Route and Speed Signalling................................................... 15
  6.1 Lineside signals............................................................. 15
  6.2 In-cab displays.............................................................. 15
  6.3 Past exam questions....................................................... 16

7 ERTMS ............................................................................... 17
  7.1 Past exam questions....................................................... 17

8 Braking Distance and Headway.............................................. 18
  8.1 Braking........................................................................... 18
  8.2 Headway......................................................................... 18
  8.3 Past exam questions....................................................... 18

9 Application Design ............................................................... 20
  9.1 Factors affecting application design................................. 20
  9.2 Choice of architecture/equipment................................... 21
  9.3 Process........................................................................... 21
  9.4 Past exam questions....................................................... 22

10 Interaction with Other Disciplines........................................ 23
  10.1 Track and Permanent Way............................................... 23
  10.2 Civils............................................................................ 23
  10.3 Electrification............................................................... 24
  10.4 Telecommunications....................................................... 24
  10.5 Operators/Maintainers/Drivers....................................... 25
  10.6 Past Paper Questions....................................................... 26

11 Installation, Testing and Commissioning............................... 27
  11.1 Installation................................................................. 27
  11.2 Testing......................................................................... 27
  11.3 Commissioning............................................................ 28
  11.4 Past exam questions....................................................... 29
3 Practical Guidance for the Exam

3.1 General information and instructions

The Module 3 Exam paper generally contains about 10 questions, all of which carry equal marks. Candidates must answer three questions. The questions set should include one requiring candidates to give full interlocking controls for selected signalled routes and points on a layout provided. There is often (but not always) a question relating to aspect sequences. The remaining “written” questions relate to the principles of signalling equipment and controls.

For more information on exam guidance please see the ‘Information and Guidance for Candidates’ document.

3.2 Control tables questions

The exam paper should have the following instructions (or similar)\(^1\) for the control tables question:

| If you have brought your own control tables with you to use for question 1 then these must be checked by the invigilator prior to use. |
| If your control tables include numbered “standard” notes then you must show the examiner you know the meaning of the numbers you have used, a reference to where you found them is not sufficient. |
| Control table entries involving time are more likely to get marks if the value is reasonably close than if it is entered as just “t”. You won’t lose marks for a difference of a few seconds but you should show that you know the difference between 5 seconds and 30s. |
| You are not required to include a drawn/checked/issued and date box. |
| If the interlocking practice you use is part electric/electronic and part mechanical, the locking for both should be shown. |
| Tell us which railway’s practice you have followed and state any assumptions you make. |

Take note of these points, it is a good approach to start your answer with “UK Mainline practice” (or equivalent) then add any general points such as “Comprehensive approach locking not provided”. Then define any notes you use e.g. “$10 = at time of clearance only”. You will be provided with IRSE blank signal/route and points control tables, but can choose not to use this format. If you choose not to use the IRSE provided control tables then you must provide yourself with sufficient copies of your own, and they must not have any corporate logos on. Remember to put the module and question number on each sheet (there is space for this on the IRSE blanks). Ensure that you can use your chosen format quickly and accurately under exam conditions. Good preparation for the exam will include plenty of practice on past exam layouts to ensure you know how to fill in the tables for complex layouts.

Candidates considering using Network Rail standard control tables (NR/L2/SIG/11201/ ModA18 Appendix B) or similar should understand that leaving any parts blank may lose marks. Consider creating an amended version without items which might be covered by a general note to save time such as TPWS (Train Protection Warning System), CAR (Comprehensive Approach Locking – lookback), TORR (Train Operated Route Release) etc.

See Section 14 for more details about Interlocking Control Tables.

3.3 Aspect sequence questions

Some recent Aspect Sequence questions have involved a layout with the question paper as a separate page. Remember that this can be used as part of your answer, in which case ensure your candidate number is written on it. Do not rely on there being an aspect sequence question, nor on it having a particular form as there has been significant variety in the last few years.

3.4 Written questions

All the remaining questions fall into this category. Consider using diagrams and tabular formats where they would help with clarity, or achieving a balanced answer (advantages/disadvantages questions for example). Candidates often decide in advance to answer the control tables and aspect sequence questions (as being relatively predictable) and just one written question, then rely on the wide choice to prepare just a few topics

---

\(^1\) The examiners may decide to re-word the instructions; do not assume they are exactly as quoted.
in detail. Be warned that few exam questions cover solely one topic in isolation so it is necessary to have a broad knowledge to have a chance of gaining good marks.

All questions show the number of marks allocated. Be aware of this and respond appropriately:

- it is not worth writing several pages on part of a question worth just a few marks;
- if a part of a question is worth (say) 16 marks you should aim to make 16 points;
- where a question asks for a comparison of 2 options with respect to (say) 4 characteristics, then aim for 2 marks per characteristic per option.
4 Fundamental Requirements of Train Control

The definition of a train control system includes people, processes and supporting technology:

- the word *system* refers to the train control system;
- the term *signalling system* refers to the part of the train control system implemented by means of technology.

Candidates should understand the role of signalling within the railway system and the fundamental requirements for a signalling system. The following is edited from [5]; candidates are advised to read the full document.

4.1 Operational requirements

- The system should facilitate the safe, efficient and effective use of railway infrastructure and trains; it should not intrude into running of the railway.
- The reliability, availability and maintainability of the signalling system should be sufficient to fulfil the operational requirements.
- “Degraded mode” facilities should be provided to enable trains to move when elements of the signalling system have failed.

4.2 Core functional safety requirements

- Before a train is given authority to move the section of line should be proved to be clear and to be secure against derailment and conflicts.
- After movement authority has been given, the security of the line should be maintained until:
  - the complete train has cleared the section of line, or
  - the authority has been rescinded and the train has come to a stand, or
  - the authority has been rescinded (and communicated to the train) and the train has sufficient space to come to a stand safely.
- The signaller and train driver, or automatic train operation sub-system [ATO], should be provided with unambiguous, consistent and timely information to perform their duties;
- Sufficient space should be provided between following trains to allow each train to brake to a stand safely;
- Controls should be in place to prevent and/or mitigate the consequences of:
  - trains exceeding the maximum permitted speed and
  - trains moving without authorisation.
- Protection should be provided for level crossings, engineering work etc.
- The system should provide for communication between signallers and others;
- The means should be provided for preventing trains from being routed onto a line with which they are not compatible, and to instruct a train to stop in an emergency.

4.3 Essential supporting safety requirements

- The level of safety performance of the system should meet specified targets;
- The signalling system and the associated operating rules should be compatible;
- The human factors associated with the safe operation of the system should be taken into account in the specification and design of the system;
- In the event of a failure of the signalling system, it should remain in, or revert to, a fail-safe state;
- The signalling system should not be subject to, nor be the cause of, unsafe interactions with other railway systems;
- The system should be resilient to unwanted external influences that could adversely affect the safety and availability of the system;
The arrangements for the maintenance and modification of the signalling system should ensure its continuing safe operation;

Staff who use, operate and maintain the signalling system should be demonstrably competent.

### Activity 4 a

Consider a range of different types of railway such as freight lines, urban tramways, high capacity metros, high speed passenger lines, and mixed traffic main line railway. Do the fundamental requirements apply to each of these? Are some items redundant in particular cases?

### 4.4 Past exam questions

#### Question 4 A

Signalling principles evolve with time. You are required to alter an existing interlocking or control system which was designed to older principles. Describe the factors to be considered when deciding whether to continue to apply the older principles or to apply current rules (including the extent of retrospective work).

[15 marks]

When making decisions about the scope of the works to be undertaken, how are safety constraints and commercial constraints balanced?

[10 marks]
5 Types of Train Control

There are many different methods used to control train movements on various railways.

Activity 5 a
Identify examples of the types of train control in the sections below. List the characteristics of each line that may have influenced the signalling type. Consider technical factors and also economic, performance, capacity etc.

5.1 On-sight train control

Occasionally there is little benefit to providing a signalling system. Traffic speeds, frequency, and braking performance may be such that operation under the responsibility of the driver provides adequate safety.

Activity 5 b
Investigate the operating rules for a railway using on-sight train movement. Determine how drivers are authorised to move trains, how they know the limits of movement authorities and how conflicts between trains are resolved.

5.2 Time interval working

This method of working dates from the earliest railways. After one train has entered a section of line, a following train within a fixed time (say, 5 minutes) is prevented from entering the section. This was initially done by "railway policemen" using flags or lamps, later permanent signals of various forms were introduced. Drivers seeing a signal to proceed could expect that the line was clear, however, this system cannot take account of the previous train stopping mid-section.

Activity 5 c
Examine your railway's Rule Book (or equivalent), does time interval working survive as a fall-back option when all communication fails?

5.3 Absolute block working

Absolute block working was made mandatory on passenger lines in Britain in 1889 in response to a serious accident. In certain circumstances a train can be permitted to enter an occupied section (slow speed freight, empty passenger stock shunting or stations for joining trains) provided the driver has been warned and special rules are in place. See Section 18.

In absolute block working lines are divided into "Block Sections"; only one train is permitted to occupy a block section at a time. Signallers at the entrance and exit of the block sections must follow a strict procedure to authorise trains into block sections; at the end of the section the signaller observes the tail lamp on the back of the train as proof it has left the section and is complete. In order to eliminate accidents where a preceding train stops mid-section, or carriages become detached, signallers need to be able to communicate that a complete train has left the section of line. The electric telegraph was not invented until after the earliest railways but was soon used to provide the necessary communication.

In most installations, electric block instruments are used, together with lever frames and track circuits, to enforce (some of the) absolute block working regulations, and are interlocked with signals and train detection. See Chapter 3 of [8].

Activity 5 d
Visit a line operated by absolute block; discover what type of signals and block instruments are used, and the extent of train detection and interlocking of signals. Observe the signaller's procedures and understand what reliance is placed on the signaller for safe operation of the line.
Alternatively access a simulation at www.blockpost.com.

5.4 Track circuit block working (Multiple Aspect Signalling [MAS])

Track circuit block signalling is a development of absolute block signalling where the line is divided into reasonably uniform blocks. MAS increases the line capacity compared with absolute block signalling.

Only one train is permitted per block section, defined as between one stop signal and the overlap of the next. It requires continuous train detection, which may be track circuits or axle counters. Movement authority is given to drivers via lineside signals.

Signals can only transmit a limited number of different instructions to the driver. Therefore the meaning of each signal aspect must be clearly defined in the rule book. The information presented differs significantly between route and speed signalling, see Section 6 6 and 15.
Lineside signals must be placed at appropriate spacing to suit:

- First and foremost the braking characteristics of the train using the line;
- capacity and throughput required;
- all possible signal aspects;
- the characteristics of all trains using the line;
- train speeds;
- gradients;
- the geographical layout;
- Operational flexibility.

This design task is the basis of the IRSE Exam Module 2.

**Activity 5 e**

Study the official meanings of signal aspects for the railway you are most familiar with. Compare these with one or more other railway authorities ([6] may be helpful).

Study signalling plans and aspect sequence charts (see Section 15) for your railway and determine what aspects are displayed in different situations.

Establish how permissive train movements (see Section 18) are authorised.

### 5.4.1 UK Mainline MAS

For a more detailed description than this summary, see [3].

There are 4 main aspects:

- **Red:** danger, stop;
- **Yellow:** caution, be prepared to stop at the next signal;
- **Double Yellow:** preliminary caution, expect the next signal to be displaying caution;
- **Green:** clear, expect the next signal to be displaying a proceed aspect.

First caution should be at least braking distance from the stop signal ahead, so that the driver can stop the train before the signal. If sighting of the signal is poor a Banner Repeater may be required to give earlier information.

Shunting and permissive moves are authorised by position light signals which can either be separate ground-mounted signals or associated with a main signal.

Signals approaching facing junctions normally have route indicators to inform the driver which route is set (Route signalling, see Section 6). These are generally either Position Light Junction Indicators (JI, aka. “feather”), Standard Alpha-numeric Route indicators (SI) or Miniature Alpha-numeric Route indicators (MI, for shunting and permissive routes). Diverging routes often have approach control to ensure that a driver does not see a proceed aspect before the associated indication. Provision of flashing yellow aspect sequences in the previous signal(s) are sometimes used as a warning of the divergence.

---

[6] UK Mainline Standard GK/RT0057 specifies the numbering which refers to the 6 different positions of a JI.
Figure 5-1 Example of signal aspects and spacing

Figure 5-2 Photo of a four aspect signal with double yellow showing and a position 4 junction indicator in the UK
5.6 Communication Based Train Control (CBTC)
The terms “Communication Based Train Control” and “transmission-based signalling” (TBS) do not have a unified interpretation; here it is used to describe systems where movement authorities are given to drivers via a display in the driving cab instead of lineside signals. The train-borne equipment communicates with fixed equipment on the lineside either by radio or inductive loops in the track. Train detection is often implemented on the train (via a combination of odometry, accelerometers and balises), in which case track sections are not required for normal operation.

The reduction in lineside equipment offers advantages in reduced maintenance requirements and better availability of equipment. Key issues for CBTC include the recovery scenario when a train fails to communicate, reliability and capacity of the communications medium and knowing where the rear of the train is (train integrity monitoring).

While CBTC could be an implementation of block working (sometimes called virtual block), it usually implements moving block principles, since this provides optimum capacity. Candidates should probably assume (and state the assumption) that CBTC means moving block working, urban railway lines, Automatic Train Protection (ATP) provision and Automatic Train Operation (ATO) facilities.

5.7 Moving block working
Moving block working requires the control system to receive continual information about the exact location of all trains, which is not practicable with track sections. It therefore relies on continual communication between the central signalling system and the on-board system.

![Figure 5-3: Comparison between fixed and moving block](image)

The signalling control system calculates the length potentially occupied by “train A” on the track and uses this to define the places on the line that it is safe to authorise train “B” up to. These places are communicated to the trains, and the on-board system supervises the train speed to maintain the safety requirements. The “blocks” are now a moving safe-zone round each train.

Moving block allows trains to run closer together, while maintaining required safety margins, and thus increasing the line’s overall capacity. It is most beneficial for mass-transit railways.

**Activity 5f**
Investigate the principles of moving block and CBTC systems and create a list of the advantages and disadvantages compared to conventional lineside signalling. Thinking about the principles, operation, safety, maintenance, reliability etc.

5.8 European Train Control System (ETCS)
European train Control System is designed to be an interoperable suite of products allowing trains to operate across borders without country specific protection systems. ETCS has a number of levels. Level 1 is an ATP system applied to lineside signalling where speed and distance to go information is transmitted to the train intermittently using balises or infill loops/radio. Level 2 still uses fixed blocks and train detection but the movement authority (speed and distance) is transmitted over GSM-R data from a Radio Block Centre. Level 3 removes the need for train detection through the use of a train integrity system and can be both fixed (virtual) block or moving block. More details are in Section 7.
5.9 Past exam questions

Question 5 A
Signalling principles evolve with time. You are required to alter an existing interlocking or control system which was designed to older principles. Describe the factors to be considered when deciding whether to continue to apply the older principles or to apply current rules (including the extent of retrospective work).

When making decisions about the scope of the works to be undertaken, how are safety constraints and commercial constraints balanced?

[15 marks]

Question 5 B
A light rail system currently consists of vehicles operating on a dedicated line which is provided with point indicators and where the vehicles are driven on sight with no lineside signals.

The operator of this light rail system wishes to allow its vehicles to access a significant length of an adjacent heavy rail line which is signalled with lineside colour light signals.

List the key issues to be considered when mixing these two different types of operation and briefly outline possible signalling and operational solutions.

[25 marks]
6 Route and Speed Signalling

On most forms of railway signalling, the driver receives information that there is a need to slow down or stop from fixed lineside signals. It is currently less common to have an in-cab display either in addition to (e.g. Great Western ATP [Automatic Train Protection] in the UK) or instead of (e.g. ETCS [European Train Control System] Level 3 see Section 7) lineside signals.

6.1 Lineside signals

Where the warning is given by a lineside signal, there must be a relationship between the signal's position and the braking distance to the hazard. On a particular line there may be a variety of braking distances so the signalling must be designed for the worst case value for the type and speed of trains anticipated. It is not always the highest speed train which needs the longest distance to stop; the poorly braked train running more slowly may need a greater distance. This is one reason (the others are mainly associated with vehicle dynamics and wear-and-tear on the track formation and structures) for differential speed limits for traffic: the speed for the worse braked trains being restricted so that its braking distance becomes comparable. (For Speed Signs see Section 16.1).

Knowledge of the speed profile of a line is regarded as part of a driver's competency in the UK; it forms part of the "route knowledge" which is trained and assessed. This is an important difference with many other railways in the world and is part of the different signalling philosophies:

- Route signalling - tell the driver in which direction and how far they are authorised to proceed, so that they can use their route knowledge to determine the appropriate speed.
- Speed signalling - tell the driver to regulate their speed to a certain value.

Whereas route signalling is very heavily predominant in the UK; almost all other European railways use their own variety of speed signalling. Various combinations of steady or flashing, yellow, green (and sometimes other) colour lights are effectively a code for the speed to drive at; certain systems instead give that information in a more intuitive manner by displaying a numeric speed indication effectively in kph.

In reality the distinction is perhaps not as marked as it appears:

- In the UK although junction signals are given route indicators, it is relatively rare to inform the driver where they will be routed before the junction signal itself is visible. Where it is important for a driver to have commenced reducing speed prior to this, then approach control is applied on the junction signal. This "artificially" holds the junction signal at a restrictive aspect (usually red, but in some cases yellow) purely to ensure that the previous signal will display a restrictive aspect so that the driver commences braking; route signalling therefore imposes a form of speed control (see section 15).
- Under speed signalling, a driver who knows the line can often infer where they are routed by the speed information presented. Indeed some speed signalling systems provide a certain amount of route information as well; not all routes are equally suitable for all trains (some may be electrified whilst others are not, sometimes the structure gauge may be different) and therefore the driver needs information to know where they are routed as well as the speed to travel.

**Activity 6 a**

Try to understand the detailed differences between a route-signalled railway and a speed-signalled railway. Think about how each may "look" different on high-speed, mainline, rural and urban lines.

Consider the factors which have led to different practice being adopted.

In Belgium where there is much bi-directional signalling, the aspects for the "contra-flow" direction are differentiated from those for the normal direction by displaying flashing rather than steady proceed aspects. "Chevron" indicators are used at those signals where a train is being diverted onto the "wrong line" and again at the signal where "right line" running is to be resumed. Hence whilst route indicators are not used at geographic diverging junctions, use in this scenario assists the driver in identifying which of the next signals being displayed side by side is for their train.

6.2 In-cab displays

Sometimes the "speed codes" of the signal aspects or the "distance to go" of the route signal aspects are also passed directly to the train itself and thus can give an in-cab display.

- Systems such as TVM430 used on the French LGV (Ligne à Grande Vitesse i.e. high speed) lines and also on the HS1/CTRL (Channel Tunnel Rail Link) route from London to the Eurotunnel in the UK work in this manner; this is a full CBTC system without the need for lineside signals.
• The signal aspects within the “equi-block” signalling system widely used on Metros are in fact speed commands. These speeds are chosen such that the braking distance between any adjacent pair of speeds is the same; this distance dictating the length of the block used.

• The technology used for European Train Control System (ETCS) (see Section 7) is different but fundamentally achieves the same. Each train makes its own braking decisions based on its own performance (no need to embody the performance of a particular type of train within the signalling of the line itself). In ETCS level 2, the train receives a Movement Authority (MA) which gives information of both the gradient profile and the permitted speed profile of the section of line. It is up to the train itself to calculate where it needs to start braking in order to comply with all the speed restrictions and the extent of the MA which it has been given.

**Activity 6 b**
Think about the relative advantages and disadvantages of speed and route signalling; consider the driver interface, traffic capacity and degraded operation.

**Activity 6 c**
Think about the relative advantages and disadvantages of in-cab signalling, including initial commissioning, modifications, operation and maintenance.
How do these differ for overlay (where lineside equipment remains in place) and systems without lineside signals?

### 6.3 Past exam questions

**Question 6 A**
It is argued that if the driver is solely supplied with the authorised/advisory speed they do not need to know the routing that they will be taking through a junction. Discuss the reasons for this statement and explain in what circumstances it may not be correct. Include in your answer any assumptions about the signalling system and operational rules. [25 marks]

**Question 6 B**
Different railway administrations utilise “distance to go”, “route based” or “speed” signalling, sometimes in combination.

Briefly describe how one of the above styles is implemented. [7 marks]

Identify the information a driver requires from any signalling system in order to correctly manage the train. [6 marks]

Describe how each style of signalling provides the required information to the driver including the potential for errors by the signaller or driver to be managed. [12 marks]
7 ERTMS

The European Rail Traffic Management System (ERTMS) is a specification for a railway control system including infrastructure, power, rolling stock and so on, designed to give railway interoperability across borders. It is an implementation of Communication Based Train Control (CBTC). The European Train Control System (ETCS) is one part of that, covering the control, command and signalling elements.

Interoperability is an important part of European Commission transport policy, therefore compliance with the ETCS specifications are now mandated for new, upgraded or renewed railway.

ETCS specifies several different “levels” and variants, the most significant ones are:

- Level 1 provides in-cab signalling and ATP (Automatic Train Protection) in conjunction with (existing) lineside signalling including train detection. Data is passed to trains from switchable balises.
- Level 2 provides fixed block signalling and in-cab displays with conventional train detection. Communication is mostly through radio communication (GSM-R [Global System for Mobile Communications – Railway]), with balises used for fixed information (such as absolute position). At Level 2 lineside signals are superfluous.
- Level 2 “Overlay” provides L2 functions with the lineside signals still in place; this is used as a retrofit/upgrade/fallback strategy.
- Level 3 uses on-board position reporting and train integrity monitoring so conventional train detection is not required. There are no lineside signals. Consequently moving block signalling (see Section 13) is possible.
- Finally Level 0 is used to refer to an ETCS fitted train using infrastructure not fitted with ETCS.

While ERTMS has been defined for use in the European Union, it is also being used in other countries such as New Zealand, China, India and Saudi Arabia.

For information about ETCS refer to Chapter 18 of [9], the ERTMS website (www.ertms.net) and the 2009 Module 2 Study Guide Appendix P. Definitions can be found at http://www.era.europa.eu/Document-Register/Documents/SUBSET-023%20v310.pdf.

7.1 Past exam questions

Question 7 A

A route is to be provided with both lineside signals (based on distance to go rather than speed) and a cab signalling system. Some trains will be fitted with the cab signalling system, others will not.

Describe how the two signalling systems may be integrated and how to address the problem of contradictory information being presented to the driver. [15 marks]

It is proposed to sub-divide some of the lineside sections for cab signalling fitted trains only. Describe the changes required to the lineside signals and to the operating rules to enable this to take place. [10 marks]
8 Braking Distance and Headway

8.1 Braking

A feature of railways is the low friction between steel rails and steel wheels; this has its advantages but means long distances to stop are required. Trains can also be extremely heavy and/ or travel at considerable speeds; a moving train therefore has significant momentum and there is a lot of kinetic energy to convert to other forms of energy during the process of stopping a train. Hence braking assumes a much bigger significance within the design of a railway system than it is within the design of a road network for example.

The warning to brake for an unseen hazard is the most important piece of information to transfer to the driver. The concept of braking distance (i.e. the distance required for a train to brake to a stand from its highest permissible speed at that position) is an important consideration for almost all railways:

- A tramway type metro operating slow light trains with good brakes could give enough warning to a driver by ensuring good signal sighting, thus allowing trains the required braking distance from sight of the red aspect;
- In practice many metros provide repeater signals to give more warning. These are generally not placed at braking distance but relatively close to main signal to maximise their approach view. Such provision of a separate signal permits the stop signal itself to be positioned precisely where it is needed without the need to be too much concerned about its long distance sighting. Hence whereas braking distance does not affect the inter signal spacing in this environment, it is relevant to the placement of individual signals - it effectively dictates the minimum distance over which they must be effective in all conditions of visibility;
- Mainlines tend to operate fast and/or heavy trains; braking distances tend to be high (exceeding one mile/1600m) far exceeding the distance at which a driver could see a signal reliably. A distant signal is provided to warn drivers and signal spacing (distant to stop) is generally comparable with braking distances (as seen in Error! Reference source not found.).

8.2 Headway

Headway is a measure of capacity, i.e. the minimum time between following trains or the maximum frequency. Headway is expressed either as a time interval (e.g. 5 minutes) or as a frequency e.g. 24 trains per hour.

Headway is dependent on a number of things:

- maximum train speed;
- train braking characteristics (worst case for mixed traffic);
- gradients;
- train length;
- overlap lengths;
- sighting allowances;
- type of signalling;
- signal spacing, influenced by positions of features such as junctions and tunnels;
- stopping patterns.

These factors make calculating headway for a large signalling project very complex. Usually a computer model will be used to verify initial design, optimise the layout and confirm that it is possible to operate the intended timetable. Computer modelling also allows abnormal operation to be simulated.

Calculating headways is covered in detail in Appendix G of the 2009 Module 2 Study Guide. Candidates for Module 3 need to be aware of the sensitivity of line capacity to changes in track layout. They should be able to produce simple calculations/graphs to demonstrate understanding of the factors determining line capacity.

8.3 Past exam questions

Some of the recent questions relating to aspect sequences have required an understanding of braking distances and headway.
Question 8 A

Automatic Train Protection (ATP) requires the system to contain an accurate braking model for the train. List the factors you consider the ATP system should take into account. [7 marks]

Describe the impact the braking model might have on the driver’s reliance on route knowledge and driving technique. [10 marks]

Discuss the potential operational issues that need to be considered when implementing ATP. [8 marks]

Question 8 B

Excess signal spacing (defined as a distance between the first cautionary aspect and the stop aspect exceeding the specified minimum braking distance) is usually considered during scheme design. List some of the risk issues to be considered when assessing whether excess signal spacing is tolerable and how an acceptable limit without further analysis might be established. [15 marks]

In reality some trains may be able to stop in a significantly shorter distance than the ‘minimum braking distance’ specified for use in signalling design. List three reasons for this and discuss how this may affect the risk assessment. [10 marks]

Question 8 C

A signalling system based on UK mainline practice uses aspects of Green, Double Yellow, Single Yellow and Red.

Explain any rules which you would expect to apply relating to the absolute and relative separations of the signals with relation to the minimum stopping distance of the different types of train using the route. [9 marks]

In a particular situation, it is required to bring a train closer to an occupied station such that potentially the yellow to red distance will be relatively short compared to the minimum stopping distance. Discuss the risks of uneven signal spacing or an additional (or closing up) signal at significantly less than normal signal spacing, proposing any special controls which could be applied for this situation. [8 marks]

Discuss the risks of drivers receiving repeated cautionary aspects on a regular basis and any considerations when designing aspect sequences with repeated cautionary aspects. [8 marks]

Question 8 D

A double track main line with 200km/h line speed is equipped with 4 aspect signals at 1200m spacing has a freight loop 700m long (i.e. a train 700m long can stand in there clear of the traps and signals). The points at both ends of the loop have a 35km/h turnout speed. The loop entry is just clear of the overlap of one of the 4 aspect signals. Individual turnout lengths are 30m, double that for the crossover including the traps. The express trains travel at 140 km/h and are 180m long with a service brake rate of 0.85m/s/s and an acceleration of 0.5m/s/s. The freight trains can be assumed to brake and accelerate at 0.5m/s/s.

What is the minimum time required to put a 500m freight train into the loop, allow a passenger train to pass without seeing adverse aspects, and bring the freight train out of the loop and back up to its maximum speed of 95km/h?

Explain any assumptions you make, including those about the signalling systems and response times.

What difference, if any, does it make if the freight train is given a yellow aspect to leave the loop as soon as possible, or if route setting is delayed to start it with a green aspect?
9 Application Design

Once there is a functional specification for a signalling project, there are a number of decisions to make during conceptual and detailed design processes. The design is influenced not just by the specifications, but also other factors.

The study guides for modules 1 and 7 will cover this section in more detail.

Over the history of the railways, signal engineers have strived to eliminate the potential for human error. Sometimes automation can lead to mistakes as people become less familiar with how to undertake those tasks - for instance, think of a driver with ATO, how well will they be able to drive if ATO is not available? Many questions ask you to think about the impact of the system or your decisions on people - you may not have driven a train but thinking about how the driver may receive, interpret and act on information can be based on your experience of driving a car or operating machinery.

9.1 Factors affecting application design

9.1.1 Economic factors

For any capital project to be successful it must deliver the requirements with a satisfactory return on investment. Requirements and benefits may be those of stakeholders other than the customer, such as the government or general population. Projects may also be viewed as of “strategic” importance and justified by something other than financial returns.

When developing a signalling scheme, there will usually be a stage when various options for fulfilling the functional specifications are compared and evaluated. This generally involves some economic evaluation.

9.1.2 Risks

An existing railway will have assessed and understood the hazards of their system either formally or through accumulated operational experience. Signalling design for a new railway, new signalling system, or changes to an existing one will incorporate changes or novel features which introduce new hazards and affect the risk associated with existing hazards. These need to be identified and considered.

Risks considered need to include those related with the installation and commissioning period, as well as operation and maintenance activities.

Risks, hazards and mitigation are covered in more detail in Module 1 and 7 Study Guides.

9.1.3 RAMS

Reliability, Availability, Maintainability and Safety (RAMS) covers some of the non-functional requirements of a system. While they are sometimes specified numerically, they might be expressed as “at least as good as other/previous schemes”. RAMS is covered in more detail in Module 1 and 7 Study Guides.

Calculations of reliability, availability and maintainability look at the frequency of failure of individual components, evaluate the effects on the whole system, then estimate the time taken to repair or replace components and return the system to operation. Statistical mathematics then predicts the properties for the whole system, and can be used to indicate where duplicated redundant components should be considered. As it takes an unrealistically long time to get statistically significant data for new equipment where failure is rare, projects often have to demonstrate performance in other ways.

9.1.4 Human factors

A Railway System includes people – signallers, drivers, operators, maintainers. Poor design, which fails to take human capabilities and needs into account, risks increasing the likelihood of errors and thus incidents.

Signalling systems generally include a number of safeguards to guard against human error or to mitigate the consequences. Examples include ATP (Automatic Train Protection) for drivers, ARS (Automatic Route Setting) to reduce signaller workload, LED and light weight signals to reduce maintenance risks.

9.1.5 Passengers

The rail passengers are the final user of the system and so should be considered at all aspects of design, construction, operation and maintenance. This could be for example thinking about the best ways of getting passengers efficiently from A to B (in normal, abnormal and degraded conditions), the best way of informing passengers about disruption (or potential disruption) or ensuring that passengers have a comfortable journey.
9.1.6 Safety

Safety is paramount on the railway and a signalling system is primarily in place to maintain safety. Safety should be considered, analysed and mitigated against at every level of the lifecycle of the system. Safety should be built into design and safety should be considered when undertaking engineering work and/or maintenance. More information on safety is detailed in Module 1.

9.2 Choice of architecture/equipment

Several factors influence the choice of the most appropriate system architecture and equipment for a scheme, including:

- past practice and existing sub-systems;
- customer standards/specifications;
- products which are approved for use, or preferred by the customer;
- the operating environment including temperatures, dust, EMC etc.;
- local factors such as availability of power, telecoms, space in equipment rooms;
- maintenance issues such as access, spares availability;
- compatibility with existing systems and future plans (ETCS overlay for example);
- product availability including lead times and how long the supplier support continues;
- costs including initial capital cost and full life cycle cost.

While some systems can be chosen independently of each other, the interfaces do need to be considered. Systems Architecture design is intended to identify the sub-systems and how they are connected. Safety and availability requirements are then allocated to the different sub-systems. Elements of a project which might be independently chosen could include:

- Control Interface (Panel or VDU);
- Interlocking type/technology;
- Signals types and structures;
- Point mechanisms;
- Train detection type;
- Level crossings;
- Signalling power supply;
- Equipment housings.

9.3 Process

It is necessary to define a clear process for application design and engineering in order to ensure good quality, reliable work. Projects must, therefore, follow good practice such as the procedures defined in the ISO9001 International Standard for Quality Management Systems. Signalling projects particularly focus on:

- traceability and configuration control of all (source) documents;
- configuration management of design outputs;
- recording of design decisions including justification;
- the verification and validation process;
- competence management of all staff in design, installation, testing, operations and maintenance.
9.4 Past exam questions

None
10 Interaction with Other Disciplines

The railway is a system and all parts of that system need to work together to produce one that is fit for purpose, safe and cost effective. Therefore, as a signalling engineer it is important to understand the effects that:

- Signalling equipment has on other disciplines (e.g. train detection vs p-way, signal posts vs electrification posts, signal posts vs platform length, signalling position vs cab viewpoint etc.)
- Other parts of railway infrastructure have on signalling principles and layouts (e.g. position of electrification posts means moving a signal post, longer or shorter trains/stations affecting signal siting and positioning etc.).
- Cab signalling has on the traditional division between rolling stock and lineside responsibilities.

The signalling engineer should liaise and work with these disciplines and suitable Inter-Disciplinary Checks and Reviews (IDCs and IDR) should be undertaken. These reviews are covered in Module 1 – in this module the candidate needs to understand the impact of the design on signalling principles and layouts. The candidate must also remember that engineering decisions often incur commercial implications (which can be positive or negative).

Exam hint: It is more likely that this section will come up as part of a question rather than a question by itself. So it is good to understand this section in relation to other sections of the syllabus.

Activity 10a
Attend an IDR/IDR to understand how different disciplines interact.

Spend some time (possibly on a secondment) with other disciplines.

Attend a signal sighting session (or talk to members of a signal sighting committee) to understand the issues associated with other disciplines when positioning signalling equipment.

10.1 Track and Permanent Way
(In the UK permanent way (P-Way) denotes the track and track bed i.e. rails, sleepers, ballast.)

Activity 10b
Think about how track design can affect the signalling principles?

Hint: in terms of train detection, location of p-way, S&C etc.

There are many instances where the track design can affect signalling principles (the list below is an example there are others as well):

- Location of S&C – how many point ends required, flank protection, routes, facing point locking, train detection etc.
- P-Way: Positioning of bonding, breathers, etc. can affect location of train detection equipment (especially when axle counters have to be drilled to the rails).

10.2 Civils

Activity 10b
Think about how infrastructure (stations, tunnels, limited clearance, bridges etc.) can affect the signalling principles?

The positioning of signals can be affected by civil infrastructure – this could include tunnels and bridges. It is not recommended to position signals in tunnels unless absolutely necessary due to the unsafe nature of stopping a train inside a tunnel (risks include: build-up of fumes, passenger egress in an emergency is more dangerous etc.)

Civil infrastructure can also affect signal siting as the optimum siting point of the signal could be blocked by a bridge etc. Therefore, the positioning of the signal would need to be altered which could affect the headway calculations.

When civil infrastructure changes (e.g. a new bridge is built) then the impact on the signalling system must be considered to ensure that the system is not negatively affected (e.g. signal sighting is lost).
Stations can impact signalling layouts as signals can only be placed at the end of platforms (unless it is a mid-platform signal and additional mitigations are put in place) to avoid customers attempting to get on/off a train that is only half in a platform.

If a station was lengthened or shortened or the train stop markers were changed then this could impact on the positioning of signalling equipment. The driver may not be able view the signal if the train stop changes, and so the signal will have to be moved or additional mitigations put in place (e.g. OFF indicator, banner repeater etc.).

Module 2 will give specifics regarding positioning of signalling equipment – however for this module it is beneficial to understand the principles behind the positions and why (and how) other disciplines have an impact on the signalling system.

**Activity 10 c**
What mitigations would be required if signalling equipment had to be placed in tunnels or on stations?

**Activity 10 d**
If a station is lengthened or shortened and the train stops in a different position, how would this affect the signalling?
What mitigations should be put in place so that the driver has good sighting of the signal?

**10.3 Electrification**

**Activity 10 e**
Think about how electrification (overhead line, third rail, fourth rail etc.) can affect the signalling principles?

Electrification design can impact signalling principles in multiple ways including (but not limited to):
- Overhead Line (OLE) stanchions affecting signalling sighting and locations.
- Electrification affecting train detection (due to traction bonds, EMC (Electro-magnetic Compatibility) affecting the equipment – although this is covered in greater detail in module 5, need for redundancy and diversity for signalling power supplies etc.).
- Electrified trains can often have better acceleration, which can effect line speeds and spacing of trains.
- Electrified trains can be longer – possibly causing signal spacing issues.
- The need to re-signal before an electrification project happens to immunise the signalling system.

**10.4 Telecommunications**

**Activity 10 f**
Think about how telecommunications can affect the signalling principles?

Telecommunications and signalling go hand-in-hand and with the advance of modern signalling systems that use a computer based interlocking, ERTMS etc. then telecommunication networks become more important.

The telecommunications system can be part of the signalling system and could even be used to transmit safety critical information from trackside to the control centre (as in the case of Frauscher axle counters used on the UK Mainline). The impact on changes to this network must be considered when undertaking signalling design to ensure that these safety critical features are not lost.

At a higher level of ERTMS (or equivalent) then radio control is a pivotal part of the system (see section 7 ) and so the telecommunications design can have a major impact on signalling principles.

There is also a significant increase in the use of IP networks and the future of interconnectivity between all aspects of the railway sector (control to maintenance to passenger information to timetables etc.).

The future is focussing more on telecommunications networks, changing the signalling principles, however telecommunications are still pivotal for communication between the driver and the signaller on the current system.
On the UK Mainline, all signals have to include a method of communication to the signaller this is via a Signal Post Telephone (SPT). These SPTs are a direct link to the signaller, they can be used by the drivers to report issues and/or by all railway users in an emergency. Telephones can also be found in electrified areas (to contact the Electrical Control Operator, ECO), near S&C, at level crossings (to contact the signaller in an emergency, or to contact the signaller if a vehicle is abnormal or to contact the signaller to enable a user to cross the line with a User Worked Crossing, UWC. These telephones are all important aspects of the signalling system but are generally designed by telecommunication engineers – however they must be considered when designing the signalling system.

There are also currently methods of communication from the signaller to the cab of a train and vice-versa that use the international GSM-R radio protocol standard.

### Activity 10 g

What would happen to the signalling system if the telecommunications network went down?

Think about this question in terms of:
1. Conventional lineside signalling.
2. Cab signalling/ERTMS

Would the problems affect signalling principles?
How would you mitigate against these problems?

### 10.5 Operators/Maintainers/Drivers

The operator has to use the system that is designed and built to be able to run trains to a tight timetable. Any delays can cause significant costs (financial and reputational) to the railway. Therefore, the operators are integral in the development of a signalling scheme. The system has to operate efficiently, reliably and largely automated to reduce the number of operators (signallers) required on the network. The operators also know the timetable and what must be achieved in terms of the signalling to be able to fit to this timetable and give the best possible service for passengers (and freight).

The system also has to be maintainable and so the maintainer must be able to understand the system so that they can maintain it to enable them to look after the system to avoid delays to trains (or to return to normal service as soon as possible).

Any changes to signalling principles then the operators must agree to these changes. Scheme plans are signed off (as Approved In Principle) by the Responsible Design Engineer, Operations and Infrastructure.

The signalling system must also be built so that the operator cannot put trains in any unsafe situations. The interlocking should stop operators from creating unsafe situations by stopping these operations or by failing to a safe state.

### Activity 10 h

Consider how changes to a signalling layout could affect operations?

If you are working on a signalling project then ask the design manager or responsible design engineer what impact the operator has had on the scheme.

The driver must also be considered when designing signalling systems – particularly with reference to signal sighting. The driver should have a clear view of the line and signalling system to enable them to control their train appropriately. There is an interface between the signalling and the driver at the signal (whether it be lineside or in the cab) – this interface is important and so must be considered when designing a signalling system.

Furthermore, the drivers can impact the signalling system.

Example 1, a signal that has a high SPAD (Signal Passed at Danger) problem could actually be due to the signalling system (i.e. the signal is positioned incorrectly, the aspect sequence is wrong etc.)

Example 2, the way that a driver drives the train could pick up on an issue with the signalling system.
Activity 10 i
Think about how the driver can impact the signalling system.

Note down the interfaces between the driver and the signalling system and how these interfaces are safe, fit for purpose and cost effective.

10.6 Past Paper Questions

Question 10A
A railway operates an urban and inter-urban rail service utilising lineside signals at speeds up to 100MPH (160km/h). It is proposed to replace the current 144m long trains with trains of 184m length.

Identify three issues of infrastructure compatibility which need to be considered. [3 marks]

At stations, the stopping positions are going to be closer to the existing signals. The administration is considering moving the signals or extending the platforms in the rear. Describe the advantages, disadvantages and commercial implications of the two options. [10 marks]

At two locations it is not possible to relocate the signal or extend the platform, requiring the train to stop approximately 1.5m from the signal. Describe two possible solutions to enable the train driver to be fully aware of the signal aspect taking account of modern multiple unit design features such as restricted visibility. (Novel, practical solutions will achieve extra credit). [12 marks]

Question 10B
Automatic Train Protection (ATP) requires the system to contain an accurate braking model for the train. List the factors you consider the ATP system should take into account. [7 marks]

Describe the impact the braking model might have on the driver's reliance on route knowledge and driving technique. [10 marks]

Discuss the potential operational issues that need to be considered when implementing ATP. [8 marks]

Question 10C
A railway is introducing Automatic Train Operation (ATO). Briefly describe a suitable system. [7 marks]

Explain what benefits may be expected as a result of ATO. [10 marks]

Discuss how the performance of the ATO system may be affected by varying rail head conditions. Describe how the issues may be addressed and any changes needed to operational procedures. [8 marks]

Question 10D
Junctions often restrict the overall capacity of a railway.

A simple double track junction (double track branch diverging from a double track main line) is situated between a tunnel and a station as shown on the layout above. Explain how the signalling facilities and controls provided can affect the overall capacity of the railway in the area. [10 marks]

The double track junction is to be renewed by the track engineers on approximately the same site between the tunnel and station, with some scope to alter the layout within those constraints. As a signalling designer you have the opportunity to influence the new layout to reduce delays in the area. Briefly describe what signalling and layout options for improving junction capacity you would propose at this site. [10 marks]

What additional information about the railway would you wish to know before comparing options and choosing one? [5 marks]
11 Installation, Testing and Commissioning

All signalling systems must be thoroughly tested before being put into service because of its critical role in ensuring the safety of train operation.

Testing is necessary to confirm that new signalling installations, and alterations to existing installations, are independently tested in a manner that assures:

• Compliance with the Project specifications and Design Details; and,
• Fitness for purpose before they are offered for Entry into Operational Service.

Commissioning covers all the tasks involved in putting systems and equipment into service. The scale and scope of testing and commissioning varies widely; it is needed for everything from new railway systems to minor modifications.

Testing and commissioning are often linked, since they often take place at the same stage in a project, and are interdependent in some ways. Both activities often involve extensive liaison with other railway disciplines – civil engineering, track, electrification, telecommunications, and so on.

This section is covered in greater detail in Modules 1 and 5, however for Module 3 then the principles behind installation, testing and commissioning are explored.

11.1 Installation

Once the system has been designed then it must be installed by competent installers. The installation should only proceed when design has been approved for construction, this will ensure that the correct design is installed and subsequently version controlled (module 1 gives more information about configuration and document control).

At all stages of design thought must be given as to how the equipment needs to be installed and also maintained. Therefore the design must:

- Be installable (for example a location case that has too much equipment will mean that wiring will be difficult or impossible).
- Ensure that installation can be done with ease (as much as possible).
- Ensure that installation can be done safely (placing equipment in accessible, safe locations).
- Think about the human factors of maintenance and installation (for example, can a maintainer reach into a location case to safely fix some wiring, is the equipment labelled with sensible labels, is the equipment easily accessible from a position of safety, are high voltage cables covered, is equipment earthed correctly etc.)
- Think about how a fast change-over at commissioning can be achieved (for example, stageworks, plug couplers etc.)

Activity 11 a
Talk to installers and ask them how easy it is to install (or maintain) equipment.

Talk to installers to see any design issues that have caused problems for them.

11.2 Testing

Design for ease of testing is important. This means considering the conditions in which staff have to test the equipment; a new equipment case can be built and partially tested in the factory, simplifying on-site tasks. Equipment can be designed to allow pre-testing (i.e. taking it out of the scope of the main commissioning).

Testing systems, especially cab signalling, with a train-borne element involves additional difficulties. While a test train can be used, running it over every route in a layout is rarely feasible.

When data is involved then the data has to be tested by itself as well as in combination with the signalling system, testing of every single permutation can be complicated.

Activity 11 b
What are the challenges of testing every single route/combination of route/possible unsafe occurrences?

Find out how long it would take to test the data for every possible permutation in a complicated station area?
Activity 11c
Identify the processes and procedures used to test equipment in your own country. (Search for these standards and note the underlying principles defined)

On the UK mainline, testing (both works and maintenance) is defined in company standards:
NR/L2/SIG/30014 – Signalling Works Testing Handbook

Look through these and identify the testing principles and test plans.

11.2.1 Off-site tests

When products, equipment, systems, data or software are supplied with Test Certificates demonstrating that tests have already been satisfactorily completed off site, then these specific tests do not need to be repeated on site.

The Tester in Charge shall review the specifications used to complete the Off Site Testing, and seeking guidance from specialist Testers as necessary, identify the outstanding testing required to be completed on site. The Tester in Charge shall describe the split between off site and on site testing, and identify the integration testing required to complete the testing process, in the Test Plan.

Sub-systems which are software driven (such as computer-based interlockings) can be tested off-site. This generally means using a simulator and/or test tools and may involve a degree of automation. Testers will check the interlocking system performs both to specifications (verification) and signalling principles (validation) using methodical processes. Once the software has been fully tested off-site, testing on-site concentrates on the connections between sub-systems.

Activity 11d
Identify off-site testing activities for a project. What tools and processes are used? How do they contribute to assuring the safety of the commissioned system? To what extent does this rely on the safety integrity of the tools?

Activity 11e
Obtain a factory acceptance plan in your standards or on a project that you are working on – look through this plan and note why each item is included.

11.2.2 Integration tests

Integration testing shall be undertaken to progressively combine each equipment and sub-systems into the overall system to confirm they are compatible with each other and the overall system works correctly and, as far as practicable, meets the end users’ needs.

The requirements for integration testing differ depending on the composition of the overall system, but in most cases comprise of through testing, elements of electronic systems testing, correspondence testing and principles testing, and may also form a sub-set of tests within individual equipment or electronic systems Test Specifications.

Activity 11f
Identify the interfaces between sub-systems on a recent project. How were these interfaces tested? Was the testing carried out by individual suppliers, the main contractor, or a combination?

Activity 11g
Obtain a site acceptance plan in your standards or on a project that you are working on – look through this plan and note why each item is included.

11.3 Commissioning

Commissionings are often time-critical moments at the end of a project when the old system is recovered and the new system is revealed and testing is completed ready for the trains to run safely on the new system at the end of the period.
To enable this process to be completed then the project area is often closed to trains for a defined period and significant resource is drawn upon to ensure that all tasks are completed during this period. Any overruns can cause significant costs (and reputational damage).

The tester in charge has to be sure that the system is working safely by the end of the period to enable them to sign the system into service.

Sometimes test trains or route proving trains are run to further ensure that the system is safe for trains to run.

Key elements for success:

- thorough planning of all tasks, logistics and staffing including adequate time to cope with the unexpected;
- communication and mutual understanding of the test and commissioning requirements with other disciplines and stakeholders;
- selection of staff and competence management so they can work carefully and efficiently, and deal effectively with surprises on site;
- Design for ease of testing and commissioning activities.
- Installing and testing as much as possible before the commissioning period.
- Good understanding of progress from teams on site.

**Activity 11 h**

Obtain a copy of a commissioning Test Plan; consider the level of detail provided.

Does the test plan show which staff and/or competencies are required?

Was the commissioning successful? How is success judged?

Concise, clear and complete documentation is essential to successful commissioning. Tasks need to be clearly defined, with a simple means of recording completion.

Prior to Entry into Operational Service, all new or altered signalling system elements shall be subjected to a check to confirm that they are fully connected in their final configuration and operate correctly.

This confirmation shall include checking that all temporary test wiring and equipment has been fully disconnected, and all protecting disconnections have been reconnected.

As far as practicable, this confirmation shall include checking the operation of all points and the clearance of all signals from the control centre, checking that all crossings are under the control of the signaller and finally confirming all control centre indications are as expected. When the system includes automatically operated level crossings that have been operated locally, these checks shall include confirming that the level crossing strike in circuitry has been normalised.

**Activity 11 i**

Talk to staff involved in a commissioning; what did they find difficult or time-consuming to test or commission? Consider how the design could have been improved.

11.4 Past exam questions

**Question 11 A**

Prior to commissioning, some railways verify that a signalling interlocking is operating in accordance with design. Other railways undertake testing against the fundamental principles and attempt to “break” the logic. Discuss the advantages and disadvantages of each approach and the reliance of each approach on control tables and the design process. [25 marks]

**Question 11B**

A train has collided with a car at an automatic open level crossing, locally monitored. Both the train driver and the car driver claim that they were authorised to proceed over the crossing. Describe and explain the testing that would be carried out, to verify whether or not the level crossing control equipment is faulty.
Question 11C
A branch line is to be singled and controlled by key token.

At the branch terminus a ‘no signalman’ instrument is to be provided. The only other signalling at this place will consist of notice boards.

At the main line junction, the key token instrument is to be in a mechanical signal box, which controls semaphore signals. The branch home signal at this place is to control the release of the token at the branch terminus, and is provided with an arm repeater. There is a berth track circuit at this signal. The starting signal to the branch line is to be released by token withdrawal.

Describe and explain the tests that need to be carried out prior to commissioning of the token instruments.

Question 11D
Signalling principles evolve with time. You are required to alter an existing interlocking or control system which was designed to older principles. Describe the factors to be considered when deciding whether to continue to apply the older principles or to apply current rules (including the extent of retrospective work). [15 marks]

When making decisions about the scope of the works to be undertaken, how are safety constraints and commercial constraints balanced? [10 marks]
12 Railway Operations

Signalling design is carried out in the light of requirements to operate a normal timetable. But under normal conditions, it must also take into account shunting and what will happen when things are no longer normal. Generally railways with a fault, failure or incident use abnormal or degraded mode operation to keep a limited service running while they respond, repair, or recover. Signalling design needs to consider what abnormal or degraded modes are required, what risk is involved, and the transition back to normal operation.

12.1 Controlling shunting operations

The interface between yard and sidings with the running line may be controlled by means including, but not limited to

- Slot arrangement at the interface of two train controllers;
- Signals placed at interface of two interlocking areas/ train controllers.

In addition, there is a usually a need to protect running passenger lines from shunting moves or stabled trains in yards. These are achieved by means including, but not limited to

- Derailers placed in conjunction with protecting signals that read toward running lines;
- Layout of track that includes runoff (with Track Circuit Interrupters in track circuited areas);
- Flank protection considered in signalling the running line.

12.2 Abnormal operation

Abnormal operation covers minor deviations from timetable, pre-planned alternative timetables and so on. The designer needs to consider a range of abnormal situations; the following list gives just a few examples:

- how the system will recover from delays;
- additional or modified train movements;
- external factors such as weather, trespassers etc;
- whether there may be a need to turn back trains before the usual terminus (e.g. owing to engineering works or power loss near the terminus);
- facilities to use one track as a bi-directional single line to allow work on the adjacent line.

Activity 12a

Make an extensive list of the types of disturbance which might affect railway operation, determine the likelihood of each and the severity of disruption which could result. Consider how the signalling system for your railway copes with the various disturbances; what measures are in place to mitigate the consequences and what more could be done to increase the railway's tolerance? Under what circumstances would the cost be justified?

On the UK Mainline, Proceed on Sight Authority (PoSA) is new and can be provided to mitigate the effects of a failure which prevents signal clearance. It is a better alternative to the signaler verbally authorising a signal to be passed at danger. The aspect guarantees a “wheeled path” (i.e. all the points in route to exit signal set in position) but very little else. It would be used if the usual signal is unable to clear because of some failure, perhaps detection of points within the overlap or on the flank of the route, perhaps the TPWS of the exit signal, or a track section failure somewhere. The authority will allow the driver to pass the signal and proceed at a speed slow enough that they may stop short of any obstruction (in common with other degraded modes of operation).

There are very few PoSA aspects yet commissioned on UK Mainline, but such degraded mode aspects are more common elsewhere in Europe.

12.3 Degraded operation modes

Degraded modes generally refer to situations when the signalling system is unable to issue movement authorities, examples include:

- failure of train detection or points detection;
- power losses;
- intrusive maintenance;

IRSE Exam Module 3 Study Guide Page 31 of 87 Issue 1.1
• cable faults or theft.

It is required, therefore, to communicate with drivers to instruct them what course of action to take when their train is stopped at the signal at danger. This depends on the specific railway which defines rules that best suit their operation, the environment and the availability of communications. In general the options are:

• stop, then proceed cautiously as far as line is clear;
• stop, then proceed cautiously to a defined place, then take some further action;
• stop, contact signaller to receive instructions;
• stop and wait.

These are not necessarily exclusive; there may be a hierarchy of actions to be taken according to circumstances or elapsed time etc. The rules obviously need to define a safe course of action, but also recognise that there is a need for traffic to continue in some limited manner even in failure scenarios. Therefore they must recognise the different site situations:

• In principle at certain signals (primarily those signals on uni-directional running lines which only protect a rear-end collision with a previous train) the risk of permitting a driver to continue cautiously on their own authority is quite low.
• Conversely where there is moveable infrastructure (such as points, swing or lifting bridges, level crossing or flat intersection with another railway) a range of risks needs to be managed so proceeding cautiously is not a sufficient control measure.

A signal plate is often used to inform the driver what particular sub-set of rules to apply at that particular site. Other railways have different rules and therefore different plates are applicable. For example:

• on London Underground the “stop and proceed rule” applies to many signals; the driver does not attempt to contact the signaller before continuing,
• in France SNCF signals are denoted as either “F” or “nF” depending upon whether the signal is franchissable (i.e. can be passed after having stopped) or non-franchissable; these supplement the displayed aspect (there is a distinction between the “twin red” carré arrêt absolu and the “single red” sémaphore arrêt de block).

Activity 12 b
Investigate your own railway’s practices to learn how signals are plated and the associated operational rules which are relevant.

Activity 12 c
Investigate your own railway’s rule book to determine what actions are required for each of the following failures:
1. failure of a single point end;
2. track section failure;
3. signal not lit (aka black aspect)
4. power failure affecting all points and signals at a junction;
5. level crossing barrier fails to lower.

12.4 Interface between two or more systems
In certain areas railways operate across interfaces between different systems, for example:

• interlocking systems;
• gauge;
• signalling principles e.g. Multiple Aspect Signalling to semaphore;
• electrification.

The differences need to be managed by means of

• Signalling controls (e.g. Tollerton Control when moving between relay interlocking and CBI);
• Mixed (generally dual) gauge or rolling stock customisation;
• Training drivers and adequate signage to mitigate differences in signalling principles.

The range of possibilities is considerable and therefore the candidate is invited to research for themselves several of the options applicable to their own railway. This section does not attempt to cover the wide range of complex interfaces on various railways.

12.5 Past exam questions

Question 12 A
A set of private sidings, operated by the owner of the sidings, is connected to a passenger railway.
Discuss the method of interface between the passenger railway and the sidings for the efficient, safe passage of trains. Include in your answer a discussion of the issues to be managed. [15 marks]
The shunting and formation of trains takes place within the sidings. Describe options for the protection of the passenger lines from unauthorised movements with advantages and disadvantages. [10 marks]

Question 12 B
A railway has made the decision to convert from track circuits to axle counters.
a) Explain how signalling principles and positioning of train detection may need to change for a railway using axle counters rather than track circuits. [10 marks]
b) Explain what features may require operational and technical staff to be retrained, focusing on principles and operational rules (NOT details of manufacturer’s equipment). [15 marks]
13 Maintenance

Signalling design must take account of the need to operate and maintain the system throughout its life. Considerations include:

- safe access to signalling equipment (lineside, gantries, ladders);
- staff protection facilities;
- diagnostic and test facilities;
- systems for fault reporting (DRACAS);  
- remote monitoring and use of data for predicting/scheduling maintenance;
- choosing equipment for ease of repair/replace.

Failures often highlight how good the application of principles is and sometimes point to flaws in those principles. The investigation of wrongside failures may lead to identification of such a weakness and the question is then whether the problem is in the principles or the design application of them. Being able to think about "why" rules are in place rather than just applying them is part of what makes a good professional engineer. Not accepting at face value the reports of an issue but challenging people as to the root causes may also form the basis of part of a question.

13.1 Staff protection facilities

There are different means employed through signalling for the protection of staff during maintenance or emergency repair works.

These can include:

- Local lockout zones which isolate particular sections of railway, prohibiting signals being cleared across the area and points from being moved. These are achieved in interlocking functions of the signals. Employed in New Zealand in the Auckland electrified network;
- Patrolman's Lockout Facilities which may isolate all the signals on the area, or alternatively just the wrong direction signals. These are operated by lineside switch or key equipment in co-operation with the signaller with being controls implemented in the interlocking (UK mainline);
- Block facilities (or better known as reminder devices in SSI [Solid State Interlocking] terminology) which isolates particular signals, tracks or pointwork and prevents signaller action on them;
- Restricted speed signalling.

13.2 Diagnostic and test facilities

Diagnostic facilities for maintainers are common in CBI (Computer Based Interlocking) systems, and becoming more common in other systems also. These systems enable remote monitoring of signalling equipment which helps maintainers diagnose issues, sometimes before they develop into a fault. Recording and replay facilities can be incorporated which are crucial in fault and incident investigations.

An example of these systems are:

- MoviolaW, used in conjunction with the Westrace(Siemens) interlocking system;
- Technician's Workstations, used in conjunction with interlocking systems including SSI, Smartlock and Westlock interlockings;
- Microlok Interlocking Diagnostic, Data Logging and Replay.

13.3 Past exam questions

Question 13 A

Describe the features and method of operation of a staff protection system suitable for use where a number of staff are required independently to work on a train occupying either of a pair of tracks between platforms (as shown in the diagram below) during the 20 minute intervals between services. [25 marks]
14 Interlocking Control Tables

Unlike control tables you may produce in the design office, the purpose of the control table question in the exam is to enable you to demonstrate that you know the relevant principles and, more importantly, that you know how to apply them to a new situation. The layout often has a few features to test that understanding and although broadly UK based any interlocking principles can be applied (as long as they are stated). Since you are demonstrating your knowledge it is acceptable to add notes to explain why controls have been included - some candidates mark points in the route, points in the overlap and flank/trapping protection to show why they have included them. This can aid examiners in understanding the candidate's logic. One common error is to provide controls for a different route to the one asked for - sometimes with the point controls being for one route and the train detection for another - it may be useful to clearly mark the route on the layout.

This section of the guide is based on the 2011 IRSE Exam Module 3 layout and question. The examples and activities in this chapter assume use of the IRSE provided Control Tables and assume a UK mainline signalling principles (SSI or CBI circa 2015) thus some adaptation may be required.

Activity 14 a
Look at the layout and ensure you understand the presentation, especially signal aspects, points (including diamonds), and route tables.
Look at some other Module 3 layouts to ensure you recognise and understand features such as switch diamonds, single and double slips (see Section 19) and banner repeater (Section 15.6.2), distant and preset shunt signals (see Section 14.6.4).

Activity 14 b
Obtain copies of the IRSE Control Tables templates for routes and points and decide whether to use them, or a format you are more familiar with.
Note that elaborate Control Table formats tailored to specific interlocking technology and/or verification processes may not be the best choice for exam use.

14.1 Purpose and history of interlocking
Interlocking is provided to ensure that only safe train movements can be authorised. e.g. to prevent points moving under trains.

In the early days of the railways, signalmen were responsible for ensuring any points were set correctly before allowing a train to proceed. Mistakes were made which led to accidents, sometimes with fatalities. The concept of the interlocking of points and signals was introduced to improve safety by preventing a signalman from operating points and signals in an unsafe sequence. It was made mandatory in the UK in 1889.

Early interlocking systems used mechanical devices to implement interlocking; later electrical relays became the norm, and following that Solid-State Interlockings (SSIs). Currently interlocking of new signalling is generally implemented in software inside Computer-Based Interlockings (CBIs).

While the Interlocking and Controls for any layout should not, in principle, be dependent upon the interlocking technology, in reality there are differences in what it is feasible to implement. Additionally there is variety according to the norm in any era and region. Remember to state on your answer which railway's practice e.g. "UK mainline" or even "UK Mainline, SSI circa 2010".

14.2 Signal/Route naming
In order to specify the interlocking controls for a signal, each different route must be considered separately. Where a signal has more than one route the convention is to name the one reading furthest to the left “A”, then the next left-most “B” and so on (e.g. signal 4, route 4A). Where there is more than one route to the same exit/destination, a number is added e.g. routes 4A-1, 4A-2.

A route class is then written in brackets after the route; the 5 UK route classes are:

- (M) Main – a route from one main signal to another with a full (or reduced) overlap available, the driver is given a main aspect;
- (W) Warning – a route from one main signal to another with a restricted overlap available (full overlap not available), the driver approaches the entrance signal at red which clears to yellow when the train has been slowed down;
• (C) Call-on – a permissive move, i.e. allowing a train to be signalled onto an occupied track section, the aspect is a position light signal associated with a main signal;
• (S) Shunt – a move for shunting such as into a siding using a position light signal either associated with a main signal or independent;
• (P) PoSA or Proceed on Sight Authority – caters for line-side equipment failure by requiring route locking (in interlocking) and only points in route detected, see Section 12.2.

e.g. a signal may have both main and call-on routes 4A(M) and 4A(C).

Note that where a signal has only one route it used to be normal practice to omit the class and route letters. The IRSE may still follow this practice in the exam paper.

Activity 14c
Using the 2011 layout, list all the routes from the following signals giving the classes, exit/destination and indication:
216, 348, 349, 212, 209, 345

Interlocking Controls can be divided into 3 phases:

• Route setting in which the interlocking checks that it is safe to set a route, and if so calls points and locks the route so that it is protected;
• Aspect controls in which the conditions for a proceed aspect are tested and the appropriate aspect is determined;
• Route releasing in which the locked route is returned to normal.

14.3 Route setting and locking

In order to check whether it is safe to set a route, points must be free to move to the desired positions (if not already there) and there must be no opposing or conflicting routes already in use. Occasionally other conditions are required also.

14.3.1 Point calling

All points in a route must be called to the correct lie for the route (all route types).

For Routes with overlaps (M), (W), [and (S) unless permissive] the points in the overlap must also be called to the correct position. Facing points in the overlap may be allowed to swing, thus the availability checks when setting must check an overlap is available in at least one direction denoted [126N or 126R] on the tables. Swinging overlaps get much more complex where there are additional points in the overlap for example [132N (134N, 133N, or 134R, 135N) or 132R].

Points adjacent to the route can also be called to protect the route, including trap or catch points. Choosing points for flank protection while ensuring it does not restrict operation can be a matter of opinion!

Activity 14d
Using the 2011 layout, list all the points which must be called for each of the following routes, including which position the points are required to be in:
346A(M), 346B(S), 346C(M), 349C(M), 349C(C), 209A(M), 209A(W).

14.3.2 Sectional route locking

Any routes which require the same set of points to be set differently from each other are inherently interlocked against one another. Routes which require the points set in the same way are not interlocked in this way, thus requiring additional locking. This includes:

• different class routes to the same destination;
• back-to-back signals (i.e. at the same position);
• identical routes in the opposite direction (directly opposing).

Additionally, a route may be initially locked out by point setting but as the train proceeds points can become free to move after the train has passed them. Where this allows a conflicting route to then be set it is called an indirectly opposing route. In order to specify when a new route can be set following the passage of a train through an opposing route, the sequence of track sections that maintain route locking for the first train are specified.
Activity 14 e
Using the 2011 layout, list all the opposing routes (direct and indirect) which must be normal for each of the following routes:
346A(M), 346B(S), 346C(M), 349C(M), 349C(C), 209A(M), 209A(W).

14.4 Aspect controls

14.4.1 Point locking and detection

Before a signal can be cleared, it is necessary to prove all points in route are set, locked and detected.

Points in the overlap are not to be detected according to the most recent Network Rail standards, however, this is a very recent change. Trailing points in the overlap must be set and locked as per points in the route.

Facing points in the overlap may be part of a swinging overlap and must be set either normal or reverse. The controls for a swinging overlap must allow for the time the points take to complete their movement when the overlap is swung. Otherwise the signal will be replaced to red immediately when they are called to the opposite lie and detection is lost.

Activity 14 f
Using the 2011 layout, list all the points which must be set, locked and/or detected for each of the following routes, including which position the points are required to be in:
346A(M), 346B(S), 346C(M), 349C(M), 349C(C), 209A(M), 209A(W).

14.4.2 Track sections clear/occupied

For (M) and (W) routes, all track sections in the route and overlap must be clear, together with any foul or flank track sections. Sometimes these will be conditional on points.

Approach control [of trains] (also called approach release [of a route]) is applied to some routes to ensure the driver will not see a proceed aspect before an associated route indicator, (see Section 15.5).

For (C) routes all track sections in the route up to the permissive tracks must be clear (usually up to the platform tracks). The permissive track must be occupied or if more than one permissive track it takes the form (AA occ. or AB occ.).

The track sections required clear in shunt routes differ with different practices. It is best therefore to declare your principle and list the tracks accordingly e.g. Assuming shunt routes are not permissive (unless call-on routes present).

Under “Tracks clear” it is usual to add any track circuit interrupters associated with track sections either in the route or where the derailment could be foul of the route e.g. DA(INT).

Activity 14 g
Using the 2011 layout, list all the track sections which must be clear for each of the following routes:
346A(M), 346B(S), 346C(M), 349C(M), 349C(C), 209A(M), 209A(W).

14.4.3 Aspect sequence

The aspect a signal shows depends on the aspect of the signal ahead as described in Section 15.

Activity 14 h
Using the 2011 layout, list all the possible aspects for the following routes:
346A(M), 346B(S), 346C(M), 349C(M), 349C(C), 209A(M), 209A(W).

14.4.4 Signals and indicators proved lit

For (M) and (W) class routes the exit signal must be proved alight so that a train cannot be signalled to an unlit signal, which could result in a Signal passed at Danger (SPAD). Generally Call-on routes do not prove the exit signal alight since there will be another train at that signal. Again shunt routes vary, but routes to a Ground Position Light (GPL) marking a Limit of Shunt signal should always prove it lit.

Where a route includes distant and/or banner signals they must also be proved lit.

Generally routes with route indicators must prove the indicator lit prior to the signal aspect clearing. This ensures that a driver always sees the route indication with the proceed aspect. Where the exit signal has Train Protection and Warning System (TPWS), Automatic Train Protection (ATP) or a trainstop this is generally proved working when signalling up to the exit signal at danger.
Activity 14i
Using the 2011 layout, list all the signals and indicators which must be proved alight for each of the following routes.
346A(M), 346B(S), 346C(M), 349C(M), 349C(C), 209A(M), 209A(W).

14.5 Route disengaging and cancellation

Once a route from a signal has been utilised, the aspect is generally disengaged which prevents re-clearance once all the track sections in its route have become clear again after the train. The exception is automatic signals and those with Automatic Working Facility (see section 14.6.2) in use. Disengaging (sometimes called "signal stick unsettling") is normally specified to occur when the signal’s berth and overlap track are simultaneously occupied with the signal showing a proceed aspect.

If a route, having been set, is then cancelled, the route protection must be held until it is safe to release the locking. Firstly, if the aspect was never cleared, then the driver never received movement authority and it is safe to release the route. If the signal had cleared it is replaced to danger immediately, but the route is held locked whilst there is still a chance that the train will not be able to stop prior to the signal; this is called “approach locking”. Approach locking prevents the signaller from setting any conflicting routes until it is safe to release the approach locking when:

- the train has passed the signal (entered the route) and thus is protected by route holding (shown by sequential operation of the 1st and 2nd tracks in the route), or
- the approaching train has come to a stand at the signal (determined using an approach locking release timer), or
- Comprehensive Approach Locking (lookback) shows there is no approaching train that would be affected by reversion of a signal, taking into account the aspect sequence.

14.5.1 Approach locking release timers

This is used to determine whether an approaching train has had time to stop, or to enter the route. For the UK the times are tabulated in standards (NR/L2/SIG/30009/ GKR0063) and depend on signal spacing, whether the signal is approach control led, and whether trains always start from rest.

In the exam, best marks can be obtained by including an approximate value.

Activity 14j
Consult the standards for your railway; What (if any) approach locking release time values are used and how are they determined?

14.5.2 Comprehensive approach locking

Comprehensive Approach Locking, also called “lookback”, is an optional function which looks at the track sections in rear of the signal; if there are no trains approaching which would be affected by the signal being replaced to red, then the timer need not run.

When specifying the lookback track sections, all combinations of routes leading to the signal need to be considered, including any MAR (Main aspect Approach controlled from Red) controls (lookback goes no further) and flashing yellow or double red controls on the approach.

Candidates will need to decide whether to specify this control or not in the exam.

Comprehensive approach locking is currently non-preferred by Network Rail.

14.5.3 TORR

In some areas Train Operated Route Release (TORR) is provided which reduces signaller work load by automatically releasing the route after the train. TORR is a requirement where Automatic Route Setting (ARS) is provided. Candidates will need to decide whether to specify this control or not; for efficiency in the exam this is best omitted.

Where TORR is provided it is usually operated by a track sequence (e.g. AA occupied, AB clear followed by AA clear, AB occupied). This needs to be a different track sequence from the train in section proving (TISP, usually 1st and 2nd tracks) therefore berth and first tracks are often the default, or second and third tracks as an alternative where there is permissive working or no berth track.

14.6 Other features

Methods of interfacing with sidings are discussed in Section 12.1.
14.6.1 SPAD detection and mitigation

Controls may be specified to replace signals to danger when a SPAD occurs in order to provide mitigation against the consequences. This safety function may be applied in the interlocking or elsewhere in the signalling system.

Activity 14 k
Determine what mitigation is required for SPADs according to the standards for your railway. If this is implemented in the interlocking, what controls should be specified?

14.6.2 Auto buttons

It is common for controlled signals to be associated with “auto” buttons which allow routes from that signal to work automatically. The candidate must choose which routes to apply this to if it is not specified in the route tables, e.g. routes on the main line only.

14.6.3 AWS, TPWS and/or ATP

While there are no boxes on IRSE tables for automatic warning system (AWS), and/or TPWS, and/or ATP, the candidate should not just ignore them. They can be covered by a note either on the table, or separately, such as with a list of assumptions since providing full details on every control table is not an efficient use of exam time.

14.6.4 Preset shunt signals

Occasionally, a railway layout may be designed with a shunt signal on the line of a main class route, where a train on the main route must pass it. On some railways the shunt signal must be preset to show a proceed aspect when a main class route is set past it, on others drivers are expected to know when a shunt signal can be passed at red in this scenario.

The full controls are complex but include: the Main route is not permitted to set when the shunt route is in use and vice versa; and the Main signal cannot show proceed until the shunt signal is proved off.

14.6.5 Co-acting signals

Where it is necessary to provide adequate sighting, a second signal head may be provided duplicating the aspect of the primary signal head and (usually) any route indications. There is a risk that in a failure situation the two signals will display different aspects so special controls are required to ensure graceful degradation modes.

At Nottingham Station a co-acting signal is in the same position but at 90 degrees to the primary signal to assist drivers of trains which must stop very close to the signal.

Elsewhere the co-actor may be on the opposite side of the line to cater for with line curvature, station canopies etc. The example shown below shows the up main platform starter signals at East Midlands Parkway station. It is not an ideal arrangement since it could be mistaken for a wrong direction (down direction) platform starter signal for the up main line.

---

4 East Midlands Parkway is situated north of Leicester on the UK’s Midland Mainline, it was opened in 2009.
14.6.6 Ground frames and sidings

There is no single way that ground frames, shunting yards and sidings are controlled. Some examples are:

- There may be a “release” from the Signal Box allowing staff to take control of a ground frame; to return control to the signal box would require the ground frame returned to its Normal state;
- Where yards or sidings are under the control of a shunter an “acceptance switch” can be used to allow the signaller to route trains into the area under the shunter’s control.
Activity 14 I
Determine what methods are used to control ground frames and shunting yards for your railway. What controls should be implemented in the interlocking, and what procedures followed by signaller/driver/shunter?

14.7 Points control tables

The IRSE Points Control Tables are divided into two parts horizontally; the top part specifies controls to call the points Normal to Reverse (N>R), the bottom is for calling the points Reverse to Normal (R>N). The first column relates to the routes which do the calling and the other columns to the locking conditions which would prevent that movement if it would not be safe for the point movement to take place.

If your local practice is to describe points as lying Left or Right it would be reasonable to use this convention provided you describe clearly to the examiner what this means (i.e. train takes divergence to the left or left-hand switch closed; these are opposite definitions).

14.7.1 Points deadlocking

Points cannot be allowed to move when a train is crossing them, therefore, the track section(s) that the points are in must be proved clear.

Other track sections may be foul of routes over the points either normal or reverse. If these tracks are occupied, a train may be conditionally foul, depending on the lie of the points. A typical instance of this is at a double junction (see diagram) where track AB is foul of routes over 302 reverse, and therefore is required clear unless points 301 are reverse and thus the locking to specify is: (AB or 301R). Similarly routes over points 301 normal will require track CF clear or points 302 normal.

Activity 14 m
Using the 2011 layout, list all the tracks which must be clear to allow the following points to move N>R and R>N.
146, 126, 132, 135, 137.

14.7.2 Called normal/reverse

Each set of points will be called (N or R) by:

- all routes over the points;
- all routes for which the points are trailing in the overlap;
- any routes which require them to provide flank or trapping protection.

Activity 14 n
Using the 2011 layout, list all the routes which require the following points to be called N>R; list the routes which require the following points to be called R>N.
146, 126, 132, 135, 137.
14.7.3 Sectional route locking
Points can only be set if they are free to move and therefore must not be called unless all routes requiring them in the other position are normal (not set). Similarly, points in an overlap (unless swinging) cannot be called unless all routes over them in the other position are normal.

Where sectional route locking is provided to maintain points locking in front of a train, it is necessary to list the track sections which must be clear before the points become available to be called.

Where the points are required in one position by a fixed overlap, the points can be freed to move to the other position once the train has been proved to a stand at the exit signal by timing on the exit signal's berth track section, i.e. <tracks in route> clear, (<berth track> clear or <berth track> occupied for time).

Activity 14 o
Using the 2011 layout, list all the routes which must be normal, and track sections that must be clear, to allow the following points to be called N>R and R>N. 146, 126, 132, 135, 137.

14.7.4 Swinging overlaps
Swinging overlaps may be provided to allow alternative forward routes to be set or provide flexibility for other (flanking) routes to be set. This means that at any facing points in the overlap, the overlap can be set in any direction which is currently safe; the route can set if at least one possible overlap is available. There may be additional points in the overlap (facing or trailing) which must be set and detected. It is essential that any track sections which would be in a new overlap are proved clear before calling the points to swing the overlap.

Activity 14 p
Using the 2011 layout, list all the points which will have swinging overlaps, and the conditions that should be proved when testing if an overlap is available.

14.7.5 Time of operation locking
Where facing points in an overlap can swing and the points are close to the track section joint beyond the signal, it is possible that a train overrunning the signal could reach the points while they are still moving. To prevent derailment, points closer than a calculated distance from the joint are locked when the berth track section is occupied, until the train comes to a stand, determined by a timer. The distance is minimum 20m dependent on point equipment, interlocking system and train detection operational delays.

Activity 14 q
Using the 2011 layout, list all the points which will have time of operation locking, and the associated track section that will lock the points.

14.7.6 Automatic restoration
Points can be self-restored or a reminder alarm provided so that the signaller will restore them after use. Restoration is usually to the normal position to provide protection, for example a passenger line protected from moves in a siding or goods loop.

Activity 14 r
Using the 2011 layout, list all the points which would be self-restored and in which direction.

14.8 Additional considerations
The Control Table designer has to decide how much protection is provided by setting flank points. When doing the control table question in the exam, the layout must be practicable and operable (too many flank points will make the layout unusable).

If complex controls such as swinging overlaps or pre-set shunt signals are not part of your railway's local practice, don't ignore them. The examiner will not know whether you missed it, or are unsure how to apply the controls. We suggest you put a note showing you have noticed it and say it's not part of your railway's practice describing any alternative controls or operational rule.

Make sure you read carefully any details included on the layout and route boxes. Details such as approach control should be included in your control table answer.

Remember that the route tables and points tables must be consistent with each other. If you have included a points call in your route (including for flank protection) it must be shown in the points table.
14.9 Past exam questions

Candidates can attempt the Control Tables question for the past papers available on the IRSE website. Note that the format changed significantly in 2011. Papers for 2010 and earlier allocated 2/3rds of the paper’s marks to the Control Tables question, and required the candidate to create and complete control tables from blank paper.

**Question 14 A**

Using the 2011 layout 3;

a) Give the full interlocking and controls for the following signalled routes:
   216, 348C(M), and 349D(C)

b) Give the full interlocking and controls for the following points:
   133

**Examiners’ comments**

- A few candidates seemed to struggle with time;
- The routes were not easy;
- Some managed to provide controls for the wrong routes;
- The normal lie of some points caught people out;
- The overlaps were a challenge to some;
- Foul tracks, flank and trapping protection needed care;
- State your principles – “Tell us which railway’s practice you have followed”;
- Don’t just apply loads of dollar notes if you don’t understand what they are for!

**Additional comments from exam review**

Considering route 216 to 212, at first sight it might look simple, but many did not recognise that there were complications: Conflicting overlap; Opposing route to 217; Banner Repeater; Flashing aspects.

Overall there was broadly a 50:50 split between the use of the IRSE supplied blank CT and the use of a candidate’s own supply, which were often the Network Rail 11202 issue 3 standard or a variant thereof. Note that these are not ideal for exam conditions as they have boxes for the entry of what the IRSE regard as non-essential items (e.g. TACL, TORR, AWS), yet the candidate can’t simply leave these blank. It is best to use a form of column format as this is quicker when completing various routes that are similar and can put “same as above except for….”

**Question 14 B**

A signalling system is to be equipped with automatic route release after the passage of a train. Describe what initiates the release and what conditions need to be checked. [13 marks]

Discuss the appropriate levels of safety integrity for the different elements which need to be checked before a release is initiated or actioned. [12 marks]

**Question 14 C**

Using the 2010 layout 3;

a) Give the full interlocking and controls for the following signalled routes:
   473B(M), 488B(M, W and C), 468C(S)

b) Give the full interlocking and controls for the following points:
   137 and 148

**Comments from exam review**

- understanding double slips (trailing ends often missed, tracks overlooked); feeling is that many candidates don’t really understand functionality of slips.
similarly for switch diamonds; there were some who did routes with impossible point lies which proved a challenge to examiners to understand what the candidate was thinking.

- time values. Whereas accurate times aren’t needed, it is important to get the relative values sensible—often the same time value was used for Main / Warning / Call-on approach control from the same signal; sometimes even allocated the wrong way around!

**Question 14 D**

Describe a system for detecting and reacting to SPADs [Signals Passed at Danger] which is resilient to legitimate moves, rapid in response, and only affects train movements in the immediate vicinity of the SPAD. [25 marks]

If candidates wish for further practice, it is suggested that they produce control tables for further routes on the layouts.
15 Aspect Sequences

Note that this section makes specific reference to the UK Mainline practice, however the principles discussed will still apply and can be adapted for any railway practice.

15.1 Aspect sequence charts

The purpose of an aspect sequence chart is to present in a readily assimilated manner how the aspect displayed on one signal is affected by the one being displayed by the signals beyond it. Styles of depiction vary but, in general concept, lines are drawn from each signal back towards each signal that reads up to it and is affected by it.

Each of the various possible aspects (including any associated route indication) are separately depicted at each signal; the lines drawn:

- define the aspect to be shown given certain aspect(s) being displayed at the next signal (i.e. the signal may display the same aspect for one of several displayed at the signal ahead);
- define the aspect to be shown at the signal on approach (note that for any given aspect on a signal, the aspect to be displayed by a previous signal must be uniquely defined. Where there are converging junctions and thus several signals read up to the given signal, the aspects displayed at each of them may differ: this can be the case when the speed profile of these different routes are dissimilar).

Where a signal is held at a restrictive aspect until a train approaches it, then the aspect sequence chart needs to reflect this "approach control"; certain aspects of the signal in rear would therefore never be displayed in such a scenario.

15.2 2, 3 and 4 aspect sequences

The diagrams below depict standard aspect sequences for 2, 3 and 4 aspect signalling. They are suitable where the signal spacing dictated by braking considerations provides suitable headway. Note that there must always be braking distance to the Red aspect from the first caution (yellow or double yellow), but should not be significantly over-braked.

**Figure 15-1: Diagram to show a 2 aspect sequence**

**Figure 15-2: Diagram to show a 3 aspect sequence**
15.3 Aspect sequence transitions

Some consideration is necessary at a transition between 3 aspect and 4 aspect.

15.3.1 4-Aspect to 3-Aspect

A driver in 4-aspect area will be accustomed to passing signals at a nominal half braking distance with outer caution and then an inner caution signal. Entering the 3-aspect area they encounter the first signal, a Yellow, as their first and only caution; this is safe as there is full braking distance and the driver would be reassured of this by the profile of the 3-aspect signal.

For this transition, there are several options. Which one is appropriate depends on the spacing of the signals and the headway requirement in each situation. They all involve some compromise and none are without their disadvantages or risks.

The basic problem is that a driver has been encountering signals at a nominal braking distance apart, yet at the transition to 4-aspects there either there has to be:

- full braking distance between the last 3-aspect and the first 4-aspect in order that there is enough braking distance for a train to stop at it if displaying Red (in which case there is then a problem of how to warn the driver of the need to stop at the second of the 4-aspects because the place where the Double Yellow should be displayed has no signal to be able to do so), or
- nominally half braking distance between the last 3-aspect and the first 4-aspect (this conversely is fine for the forthcoming 4-aspect sequence but there is no way to warn the driver of this first 4-aspect signal being at Red because there is no signal in the suitable position).

Hence there is always a problem which needs to be overcome. Two options are given here:

15.3.3 Approach control

The FIRST 4-aspect signal is held at danger whilst the SECOND 4-Aspect head is at Red, until the train has approached it. The disadvantage of this option is its detrimental impact on headway and of drivers’ anticipation of the clearance of the aspect. The dotted line in the diagram means a timed transition.
15.3.4 4-Aspect distant

This option involves installing a 4-aspect distant signal (i.e. Yellow/Green/Yellow with no Red aspect) for the SECOND 4-aspect head. This removes the problem of how to warn of the Red on the second 4-aspect head by the simple expedient of not providing a Red.

In many ways this is the neatest arrangement, but:
- there is the cost of an additional signal which makes no contribution to headway;
- it can be inconvenient to have a non-Red signal in certain locations. There certainly should not be any points or controlled level crossings requiring a protecting signal.

15.4 Dealing with under braking

If a signal in a 3 aspect sequence has to be positioned less than braking distance (S in the diagram below) from the next signal, a modified aspect sequence is used.

15.4.1 Isolated 4 aspect sequence

Inadequate spacing of 3 aspect stop signals can be avoided by provision of an isolated 4 aspect sequence. This is shown in the diagram below, refer also to the transitions in Sections 15.3.1 and 15.3.2.

There must always be braking distance to the Red aspect from the Double Yellow displayed at the second signal to the rear.
15.4.2 Modified 3 aspect sequence

The under-braked signal has approach control applied when the following signal is at red. This ensures that the driver starts braking due to the yellow displayed behind. This will reduce the speed of the train so that there will now be braking distance to the red.

This is a non-preferred solution and other options such as amending the position of signals, reducing the permissible speed for the section of line enabling closer signal spacing, or the use of an isolated 4 aspect signal should also be considered.

15.4.3 Under-braking in 4 aspect sequences

It is not necessary for there to be half braking distance between adjacent 4-aspect signals, but it is good practice to arrange the signals to be as evenly spaced as possible, whilst taking all the other considerations for signal placement into account.

The acceptable limit is generally regarded as a “one third-two thirds rule”; e.g. the distance between adjacent signals should not be less than \( \frac{1}{3} \) nor greater than \( \frac{2}{3} \) of the distance between the double yellow and its red, and so on for every pair of signals.

15.5 Junction signalling

There are several different ways of signalling junctions in route signalling. Those most used are presented in the UK Mainline's current order of preference.

15.5.1 Main Aspect Free (MAF)

Where the speed reduction for a diverging route is small (less than or equal to 10mph,) no approach control is necessary; the train should be able to make a slight speed reduction between sighting the junction signal and passing over the junction, and there is little risk from only a marginal overspeed.
15.5.2 Approach control from Yellow with Flashing Aspects (MAY-FA)

Where the diverging route speed restriction is slightly more onerous, the junction signal is initially allowed to clear but only to yellow. It is later allowed to step up to show its true aspect, once the approach control conditions are satisfied. Flashing aspects are used on the approach to the Junction Signal to give drivers prior warning to expect to take the diverging route.

If a flashing sequence is not established early enough that the driver is presented with an adequate view of the Flashing Single Yellow (this may be because of a failure, but could just be that the signaller set the route late or the train was running too close behind an earlier train for the junction signal to clear in time), then the sequence is inhibited and it defaults to MAR (see Section 15.5.3). This is why AA should be clear before the Flashing Yellow can be displayed (as detailed by the dotted line between 3 and 5 on the chart).

![Diagram to show MAY-FA junction signalling](image)

**Figure 15-9: Diagram to show MAY-FA junction signalling**

**Activity 15 a**
Colwich control is mentioned in the above diagram. What is Colwich control? Why is it required? And in what situations would you use it? What situations could it be relaxed?

15.5.3 Main aspect Approach controlled from Red (MAR)

If the speed over a diverging route is significantly less than that over the main route, then the junction signal must have approach control. This ensures that a restrictive aspect is given at the previous signal, so that the train will be slowing down before sighting the junction signal; otherwise the train could encounter the junction too fast (since the driver would only learn that it was the diverging route which had been set too late to be able to take the junction at a safe speed).

MAR is the most restrictive form of junction signalling so the junction signal is permitted to clear as soon as it is safe to do so:

- the train has passed the signal in rear, and
- when both the signal and the junction indicator are readable by the driver.

The diagram below illustrates this, the vertical line depicting the aspect being held to Red until the approach control condition is satisfied (i.e. AB is occupied).
Since MAR gives the driver the impression that they are to stop at the junction signal, it means that the train speed is often reduced by an unnecessary amount and that full opportunity of the speed of the junction cannot be taken. It also has the disadvantage that drivers can become conditioned to expecting that the junction signal will have cleared by the time that they arrive at it. Inevitably there will be the rare occasion when the train is to be held at the junction signal and in these circumstances there can be a risk of a Signal Passed at Danger (SPAD) due to the driver’s expectation of clearance.

Effectively the route signalling system is being used to impose a crude form of speed control where it is otherwise not possible to convey to the driver the information relating to their destination at an early enough time for them to brake accordingly. An alternative is to provide items such as Splitting Distants and Preliminary Route Indicators (PRIs) to give the required routing information further back from the junction; see [12].

Note that the main aspect is qualified by the route indication i.e. when the signal displays Yellow with the Position Light Junction Indicator (JI) position 4 it is a more restrictive aspect (because of the lower permissible speed) than an unqualified Yellow.

15.6 Other Features

15.6.1 Warning class routes

A Warning aspect sequence leads to a signal with a Restricted Overlap (ROL) in addition to its full overlap. In order to mitigate the risk of a short overlap, the approaching train is approach controlled at the previous signal. A warner route is used to allow a route to be set from signal 27 at the same time as a route is set from signal 23, as points are in the overlap of signal 25.
15.6.2 Banner repeaters

If a signal has to be positioned where the sighting is poor (generally under 8 seconds of sighting time), a banner repeater is provided effectively to extend that time. The traditional banner only gives two indications: a black horizontal bar when its associated signal is at Red and a black diagonal bar (white background) whenever the signal is showing any proceed aspect. In a 4-aspect sequence, the banner OFF indication must be depicted twice on the aspect sequence chart.

A new form of banner has recently been introduced on the UK Mainline which is capable of showing the black horizontal bar against a green background when the associated signal is at Green (rather than against white, which is retained for the signal at Yellow or Double Yellow). The rationale is that on high speed railway it is the sighting of the unrestrictive aspect which is important to give the driver confidence to maintain full permissible speed when there is only going to be a brief view of the signal which could be displaying Double Yellow and therefore braking would be required. A problem when introducing them is that drivers will then associate the usual OFF indication of a banner to be denoting a restrictive aspect (whether or not that is true for the particular site); hence a particular route of railway will probably require a “campaign change” to convert many in a reasonably short timescale.

Activity 15 a
Draw an aspect sequence chart for the down direction signals on the 2011 Module 3 layout. State your assumptions.

Activity 15 b
For a 3 aspect signal with route indication, consider its purpose and meaning. What must the driver perceive, how should he react to each possible aspect & indication, and how long should be allowed for reaction time.

Repeat the exercise for a call-on aspect, distant signal, banner repeater signal etc.
15.7 Past exam questions

Question 15 A

Refer to Diagram 1 on the following page.

Draw an aspect sequence chart for ALL of the signals shown in the diagram, stating any assumptions. [25 marks]

Examiners’ comments

We were looking for:

- The correct management of the ROL – previous signal approach controlled from red;
- Junction signalling – probably approach control from red which means the preceding signals do not show better than a sequence up to red;
- Banner repeater – included in sequence;
- Management of the inadequate braking distances – repeated Y or YY, step up from Y or similar;
- All the signals in the correct arrangement with both simple and complex aspect sequences.

Read and answer the question

The question asked you to “Draw an aspect sequence chart for ALL of the signals shown in the diagram, stating any assumptions.”

- Assumptions is plural, suggesting at least 2 should be included;
- Not stating any assumptions is just throwing marks away.

Additional comments from exam review

Candidates lost marks by failing to incorporate all the signals as had been requested and also for failing to state all assumptions.

Note that annotation to explain why is also useful. Even if someone did not implement a modified aspect sequence correctly, they got some credit by drawing attention to the under-braking and knowing that the standard sequence could not be used. This shows that in the real world they would know to look things up, seek advice etc; knowing the limits of your knowledge is an essential element of competence.
**Question 15 B**

A signalling system based on UK mainline practice uses aspects of Green, Double Yellow, Single Yellow and Red.

Explain any rules which you would expect to apply relating to the absolute and relative separations of the signals with relation to the minimum stopping distance of the different types of train using the route. [9 marks]

In a particular situation, it is required to bring a train closer to an occupied station such that potentially the yellow to red distance will be relatively short compared to the minimum stopping distance. Discuss the risks of uneven signal spacing or an additional (or closing up) signal at significantly less than normal signal spacing, proposing any special controls which could be applied for this situation. [8 marks]

Discuss the risks of drivers receiving repeated cautionary aspects on a regular basis and any considerations when designing aspect sequences with repeated cautionary aspects. [8 marks]
16 Lineside Signs

Previous versions of this study guide made only passing reference to lineside signs, nor are they directly mentioned in the syllabus, however, they have been included in exam questions. Online sources provide a very comprehensive history of the signals and signs used in the UK at various times [1].

This section makes specific reference to the UK Mainline lineside signs, however the principles can be still applied across other railway practices.

16.1 Speed-related signs

In the UK, it is now normal practice to sign speeds and they are published in the sectional appendix.

The most simple speed signage consists of a number (in mph or Km/h depending on the railway convention) in black in a red circle. Where necessary an additional sign will give warning in advance of a speed restriction. Where a speed restriction only applies over diverging points this is indicated with an arrow. In some areas differential speed limits apply owing to the different braking characteristics of trains. For example 125mph for tilting trains and 100mph for other passenger trains.

Speed limits may be protection for curves, poor track conditions, weak bridges etc, or may used to reduce braking distances where correct signal spacing is otherwise impossible.

Temporary Speed Restrictions (TSRs) may be used to protect engineering works, to decrease risks following a bridge strike or where there are concerns about track quality, or other reasons.

![Figure 16-1: Example speed signs on the UK Mainline](image)

16.2 Signal post signs

There are a number of signs which are generally associated with a signal, including:

- signal identity plate, which uniquely identifies a signal using a combination of a signal box prefix code and a signal number;
- “passable plate” (previously an “auto” plate, no longer provided for new works on UK Mainline) which tells the train crew that if they are stopped at the signal for more than a prescribed time (defined in the rule book) they may proceed at caution;
- delta plate which indicates a signal with no red aspect, i.e. a distant signal.

The delta and passable plates are usually, but not always, combined with the signal number to make one plate.

![Figure 16-2: Example signal post signs on the UK Mainline](image)
Activity 16a
Investigate how your railway designates automatic signals and/or those which are passable. What action must the train crew take before they are permitted to pass the signal at Red?

16.3 Communications-related signs
Signal post telephones (SPTs) are denoted by diagonally striped black and white signs.
Radio channel indications are very similar for CSR/GSM-R etc. For the older CSR sign indicates the radio system type and channel (which the driver had to set manually); a red cross indicates the end of that section.

![Example of communications signs on the UK Mainline](image)

16.4 AWS/TPWS/ATP
There are a variety of signs specific to the various automatic warning and protections systems in use. These are most important at transitions to/from an ATP/cab signalling system, or where there is a gap.

AWS cancel boards are provided where it is not practicable to provide suppression of an AWS permanent magnet. Normally suppression means that the driver does not receive a “horn” when travelling over the line in the opposite direction to that for which the relevant signal was provided.

![Example of AWS signs on the UK Mainline](image)

16.5 Other signage
A variety of signs are used to warn drivers of level crossings, remind them to check crossings are clear and working, related whistle boards and speed restrictions.
On station platforms there may be stop boards for different trains and a variety of indications related to train dispatch.
Where there are possessions, temporary boards can be used to define the limits of the worksite.
Site specific signs are used to describe procedures for token areas, depots and shunting yards; often these are combined with a reflective STOP board that can be used as the limit of movement authority for a main class route, for example often used in a freight reception road being accessed from the mainline.

Activity 16b
For a permanent speed restriction sign, consider its purpose and meaning. What must the driver perceive, how should he react to it, and how long should be allowed for reaction time.
Repeat the exercise for an AWI, a TSR, an AWS cancel board and a radio channel indication sign.

Activity 16c
Consider the risks associated with a driver failing to see, or mis-interpreting lineside signs. What is or could be done to reduce the risk and/or mitigate the consequences?
Activity 16 d
Consider how lineside signs might contribute to the risk of SPADs. What rules regarding the position of lineside signs might provide mitigation?

16.6 Past exam questions

Question 16 A

The diagram below shows a section of railway with the position of the down direction signals which are all capable of showing a stop aspect. There are stopping and non-stopping trains to both the Down Branch and the Down Main.

Using a signalling practice you are familiar with, decide on the signal profiles (aspects and indicators) for each marked signal together with any relevant lineside signs, including speed signs if applicable.

a) Produce an aspect sequence chart for all the signals. To help explain your chart, you may mark your proposed signal profiles and signs on the diagram and submit it with your answer. [12 marks]

b) State any assumptions you have made, including any related to sighting or signals not shown on the diagram. [3 marks]

c) List all the aspects, combinations of aspects, indicators and signs that you have used with their meaning to the train driver. [5 marks]

d) Comment on how effective your proposed arrangement is in terms of maintaining the speed of a non-stop trains from the Down Main to the Down Branch. Suggest any possible improvements that could be made. Note that speed limits cannot be increased above the current speeds. [5 marks]

Your answer should clearly state which railway's practice you have used.

Diagram 1 – for use with Question 10

<table>
<thead>
<tr>
<th>Line</th>
<th>Speed (kmph)</th>
<th>Braking distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main line</td>
<td>120</td>
<td>1200</td>
</tr>
<tr>
<td>Loop</td>
<td>75</td>
<td>1050</td>
</tr>
<tr>
<td>Branch line</td>
<td>75</td>
<td>1050</td>
</tr>
<tr>
<td>Turnouts A and B</td>
<td>75</td>
<td>1050</td>
</tr>
<tr>
<td>Other turnouts</td>
<td>55</td>
<td>600</td>
</tr>
</tbody>
</table>

Candidate number ____________

Note: Up direction signals not shown for clarity
17 Single Line Controls

Where trains run in both directions on a single line, it’s obvious that the risk associated with collisions is higher than on double track railway where trains run in a single direction on each line. Additional controls are provided to reduce the risk. There are a variety of methods of control for Single Lines, below follows a brief description of the main ones; see Appendix K of the 2009 Module 2 Study Guide for more detail.

17.1 Procedural

Some low traffic railways operate largely procedurally, with the crossing places on the single line defined in the timetable, the drivers knowing which opposite direction train they need to cross where and wait at the passing loop until the crossing has occurred. Clearly there can be problems with this basic system when a train becomes very heavily delayed or cancelled altogether and late changes have to be made; there are risks that communication does not reach all who need to know or the change later becomes forgotten, potentially leading to a head-on collision.

Many railroads in North America operated satisfactorily for very many decades with a centralised control telegraphing out instructions to dispatchers at strategic places along the route to make any necessary rearrangements of crossing places. There are many variants of “Train Warrant Control” (TWC) in various parts of the world, particularly suited for lines with much “dark territory” between concentrations of signalling. See [13] for comparison with modern day ETCS Level 3 implementation on remote routes.

Whereas train graphs were originally used to plan proposed changes and record the current authorised movement authorities of each train, increasingly computers are used and this allows further safeguards to be included against human error. After some serious accidents in the early days of railways, UK legislation effectively required the adoption of some form of physical token system for the operation of single lines, but some of the heritage lines for tourists do nowadays utilise their own variant of a procedural system.

![Figure 17-1: Example of a train graph](image_url)

17.2 One Train Working (OTW)

As it says, collisions are prevented by only allowing one train into the section, applicable to single ended sections only. When the train leaves the section it must be checked to ensure it is complete, therefore an axle counter section is now the preferred option for this situation.

17.3 Train staff

The driver can only enter the single-line section when in possession of a symbol of authority called the Train Staff, which is clearly labelled with the section it belongs to. This means that a train can only pass over the section from the end where the Train Staff is, and thereafter alternately.

An improvement to this is called “staff and ticket” whereby the driver can be authorised to enter the section by receiving a written ticket and being shown the Train Staff. It must be used in combination with absolute block working, see Section 5.3. This enables a series of following trains to enter the section, with the Train Staff being given to the last train in that direction.
17.4 Token instruments

Token instruments allow a train to enter a single line section from either end provided that the section is clear. This is controlled by a number of Token Instruments which are interlocked to ensure that only one token can be removed from the machines at once. Once a token has been removed it is the driver’s authority to enter the section, and must be replaced in a token machine before another token can be removed. The token can be replaced in any machine making this system more flexible than a train staff. For a detailed description see Chapter 3 of [8].

A development of the token system is Radio Electronic Token Block (RETB) where the signaller issues an electronic token which is transmitted to the driver via radio. This is displayed on equipment in the driver's cab and handed back to the signaller via radio at the end of the section. See Chapter 3 of [8]

A further development of an electric token is the tokenless block, which avoids the physical exchange of tokens. Rather buttons or switches are fitted in signal boxes (or shunters cabins) at either end and track circuits are used to determine that a train has entered the block.
17.5 Bi-directional and reversible lines

For a double track railway operated under track circuit block with signalled running moves in both directions, there are two ways of establishing and maintaining a direction: direction switch or setting a route into the section. The direction locking must include the full length of the section, and may require enhanced locking to ensure it cannot release owing to a brief loss of train detection.

**Activity 17 a**

For each of the methods of single line control above, consider the advantages and disadvantages, including which situations it would be suited to and where it might not be appropriate.

**Activity 17 b**

Understand the principles of the different single line controls in use on your own railway practice.

Draw diagrams to show how the systems work.

17.6 Past exam questions

**Question 17 A**

A 16 km single line leads from a junction with a double track railway to a single platform terminus and is operated by a system to prove one train on the single line at a time. Describe a suitable means of controlling the line with minimal equipment along the line. [17 marks]

It is proposed to connect a heritage steam railway at the terminus with occasional through movements to/from the single line. Discuss the issues to be considered and propose two options for safely managing the movements and the single line. [8 marks]

**Question 17 B**

Describe briefly, with the aid of diagrams, two methods of signalling control of a single line between two different signalling control centres or signal boxes. [9 marks]

Describe the advantages and disadvantages of each method in the following areas:-

- Integrity of the signalling system;
- The quantity of trackside equipment and communications;
- Management of failures;
- Operational flexibility. [16 marks]
18 Permissive Working

This section makes specific reference to the UK Mainline methods, however the principles can still be applied across other railway practices.

Permissive moves are those which allow a train to enter an already occupied line. Generally these are call-on class moves to permit trains to join in a platform, or shunting moves. For more information read the UK Mainline standard GK/RT0044.

18.1 Call-on controls

Call-on routes are classified as passenger moves and thus use of call-on routes is especially risky, thus additional controls are required to mitigate risks, these include:

- A call-on route is requested using a separate exit button so the signaller must deliberately choose it;
- The signal authorising the permissive move should be relatively close to the start of the platform (used to state than 400m or a risk assessment must be carried out);
- The call-on route requires the next signal (platform exit signal) to be “On”;
- Routes from the platform exit signal require the call-on route(s) not set;
- The first train must have finished its movement, determined by using a track timer (timed to stand).

18.2 Huddersfield controls

The interlocking between a call-on route and the platform exit signal was first introduced at Huddersfield following an accident where the driver of a (second) train was accustomed to being signalled into a platform on a call-on at the same time as another (first) train was signalled out of the platform. Finally there came an occasion when the first train had not yet left the platform and the second train collided with it.

Huddersfield controls also prevent the driver of the second train “reading through” to the first train’s green signal and potentially following it into the next section.

Activity 18 a

Note down each of the potential incidents associated with permissive working. For each list the types of loss which would be associated with the incident. These should include people, rolling stock, other infrastructure, loss of service and reputation.

Identify how the controls stated above mitigate the risks you have listed.

18.3 Shunt routes

There have been a variety of different practices with shunt routes where permissive shunts are allowed.

For Network Rail’s large re-signalling schemes the most recent practice has been to provide two route identities for the permissive and non-permissive shunts (e.g. R204A(S)P and R204A(S)NP). The two routes appear identical to the driver but can be barred separately by a technician. They are selected by the interlocking on the basis of track section occupancy. In this case the controls for the non-permissive shunt, R204A(S)NP, echo those for a main route and for the permissive shunt, R204A(S)P, echo those of a call-on.

Previous practice (say 1980s) was to just omit the permissive track sections from the controls, i.e. they were not tested; neither clear nor occupied. This practice has been perpetuated in some recent re-lock projects on Network Rail.

Candidates tackling a question about permissive shunt routes, or producing control tables involving them are advised to put in a brief statement describing which principles they are following.

18.4 Freight only permissive controls

In some areas the controls necessary for permissive working can be relaxed on lines which are never used for passenger services. See UK Mainline standard GK/RT0044 and [11].

---

5 The incident was in fact at Stockport, and there were similarities with one much earlier at Newton Abbot
18.5 Past exam questions

Question 18 A

Discuss the risks associated with allowing a second train into an occupied platform and the measures that may be taken to reduce these risks. Your answer should include the situations when this feature would be used and any assumptions made about the signalling system. [25 marks]
19 Points and other track features

“Points” is the term used by signalling engineers to describe the arrangement of rails to allow junctions to be made in the track. The operation of points is primarily a mechanical task. Point operating mechanisms incorporate three basic features:

- A means of moving the point switches (blades);
- A means of securing point switches against further movement;
- A means of continuously detecting the correct position and locking of the switches.

Figure 19-1: Diagram to show the physical arrangements of points

The outside rails which are fixed are the stock rails. The two inside rails, which can move from side to side at one end, are the point blades (switch blades). The area where the wheel on one rail crosses the path of the other is known as the crossing. As the wheel rolls over the crossing there is a small area where it is only partly supported. Additional components such as check rails ensure the wheel set does not derail when passing through the area where the wheel is unsupported. The higher the speed of the turnouts, the narrower the angle of divergence, leading to the length of the gaps in the intersecting rail increasing; if the angle is too shallow then the point needs to have a swing nose crossing, see Section 19.1.

A pair of points forming the connection between two parallel lines of a double track is known as a crossover.

Figure 19-2: An example of a scissors crossover
Figure 19-3: Diagram to show the different types of crossovers

A crossover where a train (approaching in the normal direction) could cross directly from one line to the other is called a facing crossover. The mirror image, the trailing crossover requires a train to reverse to crossover from one line to the other. In areas of limited space, the two types may be superimposed on top of each other, forming a scissors crossover. These are suitable for relatively low speeds only. See Chapter 4 of [7].

19.1 Swing nose crossings

For high speed lines where the diverging route may be taken at 160km/h, the gap in the intersecting rail would be excessively long. To overcome this, the crossing is designed to have a moving portion of rail – swing nose crossing. The crossing must be treated as a separate point end.

Figure 19-4: A diagram of a swing nose crossing

19.2 Fixed and switched diamonds

Two lines crossing over each other on the level leads to the formation of rails above to make up a flat or fixed diamond crossing. There is no usable connection between the two lines involved. At each end there is an acute crossing similar to that found on a set of points, and in the middle there are two obtuse crossings. These crossings also have gaps to allow the wheel flanges through and have protective check rails, forming a ‘K’ shape. As with points, it is the length of the gaps which limit the shallowness of the angle at which the two tracks may intersect. To allow higher speed junctions, movable switch rails are provided to create a switch diamond.

Figure 19-5: Diagram of a fixed diamond crossing

Figure 19-6: Diagram of a switched diamond crossing

As with the fixed diamond, switch diamonds only allows for the intersection of train paths but not the transfer of a train from one line to another.
19.3 Single and double slips

It is possible to add rails to the outer crossings to allow movement around one of the corners. This arrangement is known as a single slip. In the figure shown below, the train would be routed via the slip connection from B – D.

![Diagram of a single slip](image)

*Figure 19-7: Diagram of a single slip*

If movements were required from A – C in the above figure then a second slip connection is added to form double slips.

![Diagram of a double slip](image)

*Figure 19-8: Diagram of a double slip*

**Activity 19 a**
Examine the 2011 Module 3 layout and identify the fixed and switched diamonds and slips.

19.4 Past exam questions

**Question 19 A**

Two double track main lines share a junction. There are at least four ways of laying out the junction as shown below:

i) Traditional double junction with plain diamond

![Diagram of a traditional double junction](image)

ii) Single lead

![Diagram of a single lead](image)
iii) Ladder

iv) Double junction with switch diamonds

Discuss the risks, possible control mitigations, and criteria for selecting both the layout and controls, which may include additional point work. [25 marks]
20 Train Detection

The track circuit is the most common way (in the UK) to detect the presence of trains, however, axle counters are increasingly chosen for resignalling schemes. Track sections are used to prove the absence of trains to allow points to be operated and signals to be cleared safely. Once a train has entered a route, the sequence of track section operation is used to maintain locking.

This module relates to the principles behind train detection and should not be confused with Module 5 – which discusses the properties, applications and limitations of train detection systems. Generally in this module you should not talk about specific manufacturer’s equipment but rather the principle of operation.

Activity 20 a
What are the differences between discrete, continuous and moving block train detection systems?
(Hint: For UK Mainline practice, NR/SP/SIG/11752 may help)

20.1 Simple track circuits

A basic track circuit consists of a power supply and adjustable resistance connected across one end of a pair of rails, and a relay connected across the other. If no train is present then the relay will be energised; if a train is on the track section or there is a broken connection the relay will be de-energised. This is fail safe as power needs to be applied to the relay to show ‘clear’, therefore if the power (or equipment) fails then the relay will drop and become de-energised – therefore showing the track section as ‘occupied’.

Figure 20-1: Track circuit block unoccupied/clear [16]

Figure 20-2: Track circuit block occupied

The diagrams above show a simplified description of a track circuit. However, it can become more complicated particularly at junctions. Track circuits are isolated from other sections through Insulated Rail Joints (IRJs). Furthermore, jointless track circuits (TI21 tracks) have also been used which use electronics to create an insulated section.
Track circuits can also be used to detect a train when using approach release on signals (see section 15). Track circuits can also be used to detect broken rails (the lack of broken rail detection is one of the biggest disadvantages of axle counters).

Track circuits can also be coded to relate information to a train when used with cab signalling. For example, TVM430 system in use on the French high speed line (and on High Speed One/Channel Tunnel Rail Link).

It should also be noted that track circuits should always be configured so that any failure will result in the section registering as occupied. Therefore, the following configurations must be followed (Note this is the case on the UK Mainline and is likely to be the case on other networks but best to confirm with your own networks’ standards).

- The track relay must be sufficiently immune to interference to prevent false energisation.
- Track circuit length must be restricted to avoid false energisation.
- An IRJ failure should not cause a false clearance and so track circuits are generally electrically staggered across the IRJ to avoid this situation (either by polarity, phase or frequency difference).

### Activity 20b
Understand the principles of a simple track circuit and how it is used to detect trains.

What are the advantages and disadvantages of simple track circuits?

What are the differences between single rail and double rail track circuits?

What are the main failure scenarios for track circuits? And how can they be mitigated against?

### 20.2 Immunisation

When track circuits are used in an electrified area (whether DC or AC) then they must be immunised to ensure that there is no interference (which could potentially show a false clear) between the electrification and the train detection.

#### 20.2.1 From AC

The traction return current flows in the single traction return rail, which can cause a false operation or damage from the high voltage drop across the rail. Therefore, the a.c. immunity of d.c. track circuits is achieved by using an a.c. immunised receiver or track relay.

#### 20.2.2 From DC

In d.c. traction areas both rails are required for the traction return currents. Therefore, only double rail track circuits can be used. At S&C it may be required to compensate for the loss of the traction return path by reinforcing it with additional negative return cables and cross bonding to other lines.

### Activity 20c
Are there other ways of immunising track circuits from a.c. and d.c. traction?

Investigate what you would do in a dual-electrification area.

### 20.3 Jointless track circuits (frequency/TI21)

IRJs can be expensive to install and to maintain and so different methods can be used to reduce the number of IRJs. One of these is a jointless track circuit where individual track sections are defined by tuned short circuits between the rails using audio frequencies. Each track circuit operates at different frequencies with a tuned zone between them (which acts as an IRJ and isolates the two sections).

Generally a fixed set of frequencies are used due to the need to specify the exact frequencies involved.
What are the advantages and disadvantages of a jointless track circuit vs a conventional track circuit?

Understand how a Jointless track circuit works.

(Hint: For UK Mainline practice, NR/SP/SIG/11752 Section 3.2 may help)

Frequency track circuits can also be used as a carrier to transmit information to a train when used with cab signalling. For example, the TVM430 system in use on the French high speed line (and on High Speed One/Channel Tunnel Rail Link) uses coded track circuits.

**20.4 Axle Counters**

Axle counters count the axles of trains as they pass a detector into or out of each track section. An evaluator makes the section occupied or clear according to the count. (i.e. if the count in = the count out then a train has passed through the section and the section shows as ‘clear’. However, if the count in does not equal the count out then the section will show as ‘occupied’).

During failure or abnormal operation the axle counter evaluator may need to be reset. Unlike track circuits this leaves uncertainty as to whether a track section is truly clear. A robust procedure is required to maintain safety in this case.

There are four principal reset scenarios:

1) Single or multiple sections miscounting after passage of a train.
2) Single or multiple section equipment failure.
3) Single or multiple sections that may be disturbed during engineering work.
4) Single or multiple sections that may require a reset after the passage of trains known to not reliably operate the axle counter system.

The scenarios above have different reset possibilities that have been designed into the axle counter system.

1) And 2) **An individual conditional or preparatory in-service reset**: the signaller has established that the section should be clear and so a reset is made of the section. This reset places aspect restriction so that a train approaching the section has to proceed at caution. This train independently establishes that the axle counter section is clear.

3) **Unconditional reset following an Engineer’s Possession Reminder (EPR)**: a premeditated act by the signaller – an EPR is applied before engineering work commences (and the sections are confirmed as clear). When the EPR is removed than the section resets and no aspect restriction is invoked (due to engineering work rules then the line should be checked as clear before it is handed back for operational use).

4) **Conditional reset utilising Special Train Reminder (STR)**: a premeditated act by the signaller prior to the passage of a Special Train. Procedures require the signaller to obtain confirmation from the train crew that the complete train has passed through the defined section, before cancelling the reminder. This will initiate the reset of affected axle counters without aspect restriction.

IRJs are not required for axle counter systems and so a significant cost is saved due to less p-way work required.
For UK Mainline practice, NR/L2/SIG/30080 ISSUE 1 is a useful standard that covers the safety and operational principles of axle counters.

**Activity 20 e**
What procedures are required when engineering work is undertaken near to or on lines that have axle counters installed?

[Think about: proximity of metal tools, metal boots etc., engineering trains, Road-Rail Vehicles, track work etc., Engineer’s Possession Reminders (EPRs)]

**Activity 20 f**
Consider the advantages and disadvantages of Track Circuits and Axle Counters in different applications.

**Activity 20 g**
Consider the impact of broken rail detection and what mitigations could be put in place when using axle counters instead of track circuits.

**Activity 20 h**
Find out more about the procedures for resetting axle counters and the mitigation of the risks.

### 20.5 Treadles

This is a mechanical or inductive device which responds to wheel flanges at a particular spot. These are used to detect the presence of a train at a location, predominantly level crossing strike-in and out. They can be used as well as track circuits or axle counters to provide a contingency.

### 20.6 Track Circuit Interrupter

A Track Circuit Interrupter (TCI) is required whenever it is necessary to be able to detect that a train has travelled beyond the place where any train should go and that it might be jeopardising the safety of other train movements; although nearly always associated with a track section this is not necessarily the case.

The simplest and most common device consists of a metal connection which is designed to get fractured by the wheel flange of a train. An interrupter is bolted to one rail and insulated from the track circuit; a simple electrical circuit is constructed taking a fused power supply through the TCI direct to a relay. Contacts of this relay are then either put in series with the track relay, or fed directly into the interlocking.

Depending upon the track layout, there is a risk that a derailed vehicle will become foul of another track. Obviously this is to be avoided as far as positioning for trap points permits but inevitably the decision often has to be taken on the basis of "the least bad of all the evils". Where a derailed train might foul an adjacent line, detection of the event (e.g. the destruction of the TCI) should not only fail its own track circuit, but protect any routes which might be fouled. Provision of the TCI as a separate interlocking input facilitates this. A further advantage is that it can be used to place the track section in an "undefined" rather than "occupied" state; the signaller’s indication shows occupied, any interlocking function that requires the track section clear is disabled, yet those functions (such as approach release or part of a track sequence to release locking) are not enabled.

#### 20.6.1 Axle counters and TCIs

Where train detection is by axle counter (AxC), once a wheel has passed the AxC head the section will remain permanently occupied until either it has cleared the section (not possible if the train has taken the route over a set of trap points leading to derailment) or until the section is reset/restore. Hence in many circumstances there is no need for a TCI since the risk that would be mitigated in the case of track circuit train detection does not exist.

Where there is a risk that a derailed vehicle could become foul of an adjacent line, a TCI is normally required, even in AxC areas. It would potentially be possible to implement the same functionality in logic, but a separate TCI has the significant virtue of simplicity.
20.6.2 Sliding buffer stop displacement detection

A further use of TCIs is not associated with train detection per se, and could be used on a line without train detection. At the end of a passenger running line, and occasionally at other sites, it is now policy to use “sliding buffer stops” which are designed to safely arrest a train following a low speed collision with the buffers. These buffers work by sliding against friction resistance and overcoming specific obstructions at intervals on its path. It is important to detect if a collision has occurred since the buffer will be displaced and no longer able to achieve its purpose. Generally this is achieved by positioning a TCI such that it is sheared off once the buffer stop is hit sufficiently that it moves. Traditionally the TCI has been wired into the associated track circuit so that the situation is revealed by an apparent track circuit failure once the train has departed; the UK Mainline current practice is to provide a separate monitoring circuit to produce a specific alarm at the signalling control centre in the event of an incident.

There are still plenty of places on the network where a line terminates at fixed buffers; in these cases a TCI may be located very close on the approach to them so that in normal circumstances a train’s wheels will not hit it. If, however, a significant collision does occur it will probably be broken as the train derails or destroys the buffer stop.

20.7 GPS, odometry, accelerometers etc.

For ETCS and all moving block systems, it is necessary for the train to determine its position accurately. Existing odometry systems are not, on their own, sufficiently accurate owing to wheel slip. It is usual for fixed (passive) balises to be used to re-set odometry. This will provide an accurate position/location to the train and can also include other information such as gradient, speed restrictions and the position of the next balise or signal.

In the USA, GPS (Global Positioning System) is used on some lines. This has significant problems for general railway use as it requires “line-of-sight” to four or more GPS satellites which is not possible in tunnels and unreliable in urban areas. It is also not accurate enough at points or adjacent lines. GPS is suitable for “dark territory” (unsignalled lines, often controlled by Track Warrants) where use is light and speeds are often low.

Various methods are used developed to supplement odometry, including accelerometers, Doppler radar. Additionally statistical methods are being investigated as a method of reducing the margin of error in odometry which would result in fewer balises required, see [15].

20.8 Past exam questions

Question 20 A

In an area without continuous track circuits, what are the risks which need to be managed after engineering works utilising rail mounted machinery? [5 marks]

Describe different means of ensuring these risks are managed for areas of axle counters or where other forms of block working are in use. Your answer should include advantages and disadvantages, the impact on performance and the balancing of risk. [20 marks]

Examiners’ comments

In an area without continuous track circuits, what are the risks which need to be managed after engineering works utilising rail mounted machinery? [5 marks]

- This is not about axle counters exclusively;
- Nor did we ask for a comparison of track circuits and axle counters;
- The issues are around plant being left, undetected, on the line;
- It is worth adding that the safety of the line after the works needs to be considered.

Describe different means of ensuring these risks are managed for areas of axle counters or where other forms of block working are in use. Your answer should include advantages and disadvantages, the impact on performance and the balancing of risk. [20 marks]

- There is the option to discuss issues relating to axle counters (not to tell us everything you know about them!);
- The relevant issues are around resetting after engineering work – the operation and principles of EPR would be appropriate;
A variety of ways of checking the line is clear can be discussed:

- Procedural – counting them out and counting them back
- Visual examination – sweep vehicle or walk through
- Sweep train – first train sent through at caution

- Which are applicable to axle counters or absolute block?
- Advantages and disadvantages of time, staffing, safety, etc.

**Question 20B**

The speed of operation of train detection systems and the propagation of status information over a transmission system can vary.

a) Discuss the causes of and the risks arising from slow or variable response times. [10 marks]

b) Describe two options for managing these risks both within and between interlockings, including advantages and disadvantages. [10 marks]

c) How could response times affect the operation of systems intended to detect unexpected train detection sequences? [5 marks]

**Question 20C**

A railway has made the decision to convert from track circuits to axle counters.

a) Explain how signalling principles and positioning of train detection may need to change for a railway using axle counters rather than track circuits. [10 marks]

b) Explain what features may require operational and technical staff to be retrained, focusing on principles and operational rules (NOT details of manufacturer’s equipment). [15 marks]

**Question 20D**

A route has been set through a complex junction. Following a train movement a section of train detection remains falsely occupied, locking the remainder of the route and a number of sets of points.

Describe facilities which could be provided to manage this situation. [5 marks]

For each facility describe the controls which would be required, with reasons, to prevent accidental operation or release of locking. [12 marks]

How might the controls and signallers processes be affected if the signaller had a computer based VDU system or a panel with lights and buttons? [8 marks]

**Question 20E**

An administration uses a route-based lineside signalling system. Describe the affect of the following failures on the ability of the system to set routes, clear aspects and cancel routes:

i) train detection section remains occupied after passage of train,

ii) train detection section shows occupied without the passage of a train,

iii) crossover fails to detect in correct position,

iv) signal aspect fails to light,

v) controlled level crossing cannot be proved operating/clear. [5 marks]

Discuss the risks associated with operating the railway whilst the system is in a failed state. [8 marks]

Describe facilities for each of the above failures which could be provided to assist the signaller in managing the failure and maintaining a safe train service. Discuss the relative merits, hazards and costs of each facility. [12 marks]
Question 20F

a) List the key principles of a track based train detection system. [5 marks]
b) A traditional signalling system is to be replaced with a transmission based signalling system which relies on the train identifying its own position. Discuss how this change in approach will affect the key principles you listed in a). [12 marks]
c) Describe the changes to the operational rules and failure response arrangements which the proposed transmission based system will require. [8 marks]

Question 20G

Discuss the factors to be considered in defining the rules for train detection section design.
Your answer should address minimum and maximum lengths and detection of vehicles at the boundaries. [15 marks]

Describe the controls to be applied to prove the extremities of a route (often called flank or foul track controls). [10 marks]

Question 20H

A single line in which train detection equipment is only at one end, e.g. One Train Working (OTW) or a single ended axle counter, requires a process for restoration following failure.

Describe a process for such a system. [25 marks]

Question 20I

a) Under what circumstances is it appropriate to provide track circuit interrupters (TCIs)? [5 marks]
b) For the circumstances you have described in a), list the risks being addressed and describe how the provision of the TCI addresses these risks. [10 marks]
c) What happens when, and after, a TCI is operated? [5 marks]
d) What difference would it make if the area was fitted with axle counters rather than track circuits? [5 marks]

Question 20J

List the key advantages and disadvantages of axle counters, single and double rail track circuits for train detection. [6 marks]

A railway administration is going to provide axle counters and needs to define the rules and system requirements for managing miscounts and failures of the axle counter equipment.

Describe the issues to be considered and appropriate control measures. [12 marks]

What issues need to be considered for the management of engineering work in axle counter areas, particularly where road-rail plant is being used? [7 marks]
21 Automatic Train Protection and Operation

Safe running of trains relies on correct understanding and response to signalling information, traditionally by drivers observing lineside signals. Some serious accidents have occurred when drivers failed to observe or react to signals (many are described in [14]). In order to protect against driver errors, various forms of Automatic Train Protection have been developed.

21.1 Mechanical train stops

Mechanical train stops consist of a trip arm mechanism mounted on the ground and a train-mounted trip cock connected to the train’s braking system. The trip arm is raised by default, in which position it will make contact with a train’s trip cock which causes emergency braking to be applied.

An electric motor or pneumatic activator drives the trip arm down when the signal is off. The pictures below illustrate a trip arm associated with a signal, and the train-mounted trip cock.

This is in use on the London Underground.

![Image of train stop device on rolling stock](image1.png)

*Figure 21-1: Example of a train stop device on rolling stock*

![Image of train stop device trackside](image2.png)

*Figure 21-2: Example of the train stop device trackside*
21.2 British Rail AWS
The Automatic Warning System (AWS) was approved in 1956 and consists of a permanent magnet and electromagnet on the approach to signals. If the signal shows green aspect the electromagnet is energised and the driver hears a bell and sees a black display. For any other aspect the electromagnet is de-energised and the driver hears a bell and sees a black and yellow display. If the warning is not acknowledged within the prescribed period of a few seconds, the train’s emergency brakes are applied.

Where AWS is used on a bi-directional line, a suppressor is used on the permanent magnet to cancel out the magnetic field. The interlocking controls must be designed to give sufficient time for the coil to become fully energised before the arrival of the train so that the train does not react to the AWS.

AWS is also used to give warning of severe speed restrictions.

AWS should be fitted to every stop signal on the UK Mainline.

![Figure 21-3: Example of an AWS](image)

21.3 TPWS
Train Protection and Warning System (TPWS) was installed in the UK following the Ladbroke Grove and Southall accidents. It is not a full Automatic Train Protection (ATP) system but provides significant mitigation against overspeed and overruns at fitted signals. When the equipment was fitted to rolling stock, the existing AWS equipment was removed and replaced with a system providing both AWS and TPWS in the same box (hence "W" in TPWS). The driver must respond to an AWS or TPWS warning or the brakes will be automatically applied.

TPWS was initially designed to ensure trains travelling at up to 75mph are stopped within the overlap of a signal. It is generally only fitted to signals protecting conflicts. Various additions have extended the applicability for higher speeds (TPWS+).

21.4 Automatic Train Protection (ATP)
Some lines are fitted with ATP systems which provide comprehensive in-cab information to the driver and continual supervision of train speed against braking curves, movement authorities and speed limits. The system uses a target speed profile to generate warnings to the train driver if they are travelling too fast. If the driver fails to respond to the warnings then the system will apply the brakes. The on-board ATP equipment is given permitted speed and location information via encoded balises, encoded track circuits or over radio.

ATP systems may be broadly grouped as continuous and intermittent:

- With intermittent ATP, balises are mounted between the rails on the approach to signals. As the information in the on-board computer can only be updated at a balise this can delay trains where the signal ahead clears after passing the previous balise. In-fill balises are sometimes positioned to improve performance;
With continuous ATP, the information is constantly received by the train. This may be achieved by radio transmission, data encoded in track circuits or by a cable laid between the rails for the full length of the block section.

ERTMS provides ATP using a combination of balises and GSM-R depending on the ETCS Level in use.

### 21.5 Automatic Train Operation (ATO)

ATO is widely used in metro applications for improved reliability and energy efficiency. ATO is able to compute optimum speed profiles for energy efficient driving while reducing variations in journey time. One of the primary reasons for providing ATO is the greater capacity which can be delivered due to eliminating the human variability in driving technique. ATO is necessary to achieve the minimum operational headway times of the highest capacity metro lines.

Metro lines are generally characterised by self-contained lines with identical trains, uniform trackside equipment, simple track layouts and intensive services. The issues of ATO fitment to Mainlines are discussed in [2].

In the UK, “attended ATO” was first used on London Underground’s Victoria Line when it opened in the 1960s, using speed-codes imposed upon the track circuits which were read by the train. The concept was widely deployed internationally including new metros in Singapore.

More modern ATO systems use on-board computers, often with track-to-train transmission via loops of cables in the track but some use radio transmission / leaky feeders (radiating cables) in tunnels. Whereas the mainline approach is to pass information to the train concerning the characteristics of the next section of line, the metro approach is generally for the train to hold this information permanently on board as a route map; this is practicable because the fleet is captive on just one line or a small network.

### 21.6 Past exam questions

**Question 21 A**

Automatic Train Protection (ATP) requires the system to contain an accurate braking model for the train. List the factors you consider the ATP system should take into account. [7 marks]

Describe the impact the braking model might have on the driver’s reliance on route knowledge and driving technique. [10 marks]

Discuss the potential operational issues that need to be considered when implementing ATP. [8 marks]

**Question 21 B**

A double track commuter line is to have its rush hour train frequency increased to the extent that ATO will be required to run a regular service with platforms that are only just long enough for the rush hour trains. Off peak services are shorter, less frequent and use a range of train types. Describe an ATP/ATO system suitable for the peak, and without ATO, for the off peak services. [25 marks]

**Question 21 C**

Discuss what weather and other factors can affect the performance of trains operating with a fixed or moving block ATP system. Discuss how these factors may be safely fed into the system on a daily basis. [25 marks]
22 Level Crossings

Level Crossings should always be seen as a compromise to save the cost associated with providing a bridge. When railways were initially built 150+ years ago there was a different paradigm, and many towns and suburbs have grown around their railway lines; it is now difficult to eliminate the historical legacy.

The interaction of pedestrians and vehicles at level crossings is a cause of many incidents and near misses; vehicular crossings are probably the highest risk area on the railway. The level of risk associated with crossings varies depending on the type of crossing, and the type, volume, speed and frequency of both road and rail traffic. There are a wide variety of arrangements ranging from rural footpaths and quiet lanes to busy main roads in complex urban areas.

Level Crossings involve many engineering disciplines, and involve other agencies principally highway authorities. There are also legislative elements.

22.1 History

Initially level crossings were manually operated either by train crew or by a local operator. If an operator was not a signaller (when a signal box was located at the crossing) then they needed to communicate with the signaller. Interlocking of crossing gates/barriers with stop signals was sometimes provided, but not always.

The diverse historical principles and practices remain in place with a variety of

- crossings with or without interlocked protecting signals;
- automatic and manually operated crossings;
- full barrier, half barrier and open crossings.

Activity 22 a

Identify the main types of level crossing permitted on the railway which you are most familiar with. How many different interfaces to the signalling system are there?

How many sets of rules are there for road users? For train drivers and signallers?

22.2 Influence on signalling systems

Level crossings may have a significant influence on signalling systems in various ways. The controls for crossings are complex and despite “typical circuits” are frequently non-standard. This complexity can cause issues of reliability and maintainability.

Manually controlled barriers increase the workload of a signaller responsible for monitoring and controlling the crossings on his workstation. Sometimes a Control Centre will have a Signaller Workstation dedicated to the (MCB-CCTV) level crossings on a section of railway.

22.3 UK level crossing types

The strategy for UK level crossings is to provide consistency to motorists in what they see. The train has the “right of way” under law (usually the enabling act authorising the initial construction of the railway). There follows a brief description of several of the key level crossing types on UK Mainline. See [10] and [4].

22.3.1 MCB-CCTV

Manually Controlled Barriers Crossing with CCTV. Features:

- barriers are controlled by a signaller who checks the crossing is clear via CCTV;
- protecting signals are interlocked with the barriers;
- barriers close the whole carriageway;
- road traffic lights provided and lamp proved
- Auto-raise and/or auto lower facilities may be provided to assist the signaller.

When the barriers are open to road traffic, protecting signals are held at red; only when the barriers are detected closed to road traffic can the signals clear to a proceed aspect. Indications confirm to the signaller that the barriers, traffic signals and power supply are working; the signaller's controls generally comprise buttons for raise, lower, emergency stop and crossing clear. These need to be positioned consistently and close to the CCTV display. CCTV camera, transmission and monitors are duplicated.
**22.3.2 MCB-OD**

Manually Controlled Barriers with Obstacle Detection. A crossing type recently introduced to UK mainline railway, this is an automatic crossing with full barriers where a combination of radar and LIDAR is used to confirm that the crossing is clear.

- crossing sequence is automatically operated by approaching trains;
- barriers close the whole carriageway;
- signaller has indications of the state of power supply, barrier position and local control operation;
- road traffic lights are provided and lamp proved.

If the crossing system is not able to detect barriers down and crossing clear at the first attempt, there is a sequence of raising and lowering barriers to try again before the signaller is alerted. There have been issues with LIDAR detectors positioned between adjacent tracks accumulating dirt and requiring regular cleaning.

**22.3.3 AHBC**

Automatic Half Barrier Crossing. Features

- crossing sequence is automatically operated by approaching trains;
- barriers close half the road on the near side;
- signaller has indications of the state of power supply, barrier position and local control operation;
- road traffic lights are provided and lamp proved;
- emergency telephones are provided.

For each line and direction of trains using the crossing, a strike-in position is determined to give 27s minimum for the road light and barrier sequence. For a double track line the strike-ins are positioned at a minimum of 37s running time and a timer is used to delay the level crossing initiation for 10s; this is to implement a minimum 10s Minimum Road Open Time should a second train on the other line be approaching the crossing.

**22.3.4 AOCL**

Automatic open crossing, locally monitored. Features:

- no barriers;
- road traffic lights provided and lamp proved;
- approaching trains automatically operate the road traffic lights;
- train driver is responsible for ensuring the crossing is clear.

On each approach an advance warning board (AWB) followed by a special speed restriction board (SSRB) warn the driver of the crossing and the maximum speed over it. The driver must have a clear view of the crossing from the SSRB, positioned at braking distance from it. An indicator at the crossing shows whether the road traffic lights and power supply are operating correctly. If the road lights have not operated (by the train striking in) the driver has a plunger (positioned to be accessible from the cab window).

AOCLs have a relatively poor safety record (largely from road users crossing while the lights are flashing) so it is unlikely that new ones would be approved. Those with a poor safety history may be retro-fitted with barriers and become an AOCL+B type crossing.

**Activity 22 b**

Find out how to calculate the position of the SSRBs, AWBs and strike-in points (or equivalent) for each type of Level crossing.

**22.3.5 MSL on bridleway/footpath crossings**

Miniature Stop Lights: Crossings for pedestrians, cyclists and horse riders are generally protected by unlocked gates which are weighted or sprung to stay closed when not in use. Whistle boards may remind the train driver to sound the horn at the appropriate place as a warning that they are approaching the crossing (not provided for new works). If a user can see far enough to get the required minimum warning time then miniature stop lights are not required. Where that is not the case a red/green light unit is provided with written instructions. In some cases a telephone to the signaller is also provided.
Activity 22 c
Once you understand how various types of Level Crossing normally operate, consider failure conditions. How would you operate the crossing in degraded mode or failure conditions? Study your railway's rulebook to see how this is done.

22.4 Selecting the appropriate crossing type
A key part of application design is selecting the appropriate crossing type for each location. This may be determined by a railway's rules, or may be dependent on individual risk-based justifications. Factors include

- pedestrian use levels;
- vehicle use levels;
- train type, speed and frequency;
- road layout;
- Other local factors e.g. a local nursing home resulting in many low mobility users.

22.4.1 Crossing closures
Closure of public level crossings is difficult. Any route with a public bridleway or footpath may require alternative provision such as a bridge or underpass requiring capital investment, possibly purchase of land, and planning consents. Replacing a footpath crossing often requires a bridge with provision for wheel chairs, which makes them very large structures.

There may need to be significant consultation with local residents, land owners, businesses and authorities before a level crossing can be closed.

Activity 22 d
Consider the various factors that might influence the choice of level crossing type. Then consult the rules for level crossings on a railway you are familiar with and compare which factors are actually taken into account.

22.5 Past exam questions

Question 22 A
“A level crossing (grade crossing) should be treated as an obstruction in the overlap/overrun”.

Discuss this statement. Your answer should consider different types of crossing, including automatic crossings, and the risks of signals passed at danger. [25 marks]

Question 22 B
A new level crossing (grade crossing) system will include four barriers completely closing the road. The barriers shall close automatically with minimal delay to rail traffic.

Derive a formula for the “strike-in” distance required for a railway running at 140km/h utilising 3 aspect lineside signalling, stating any assumptions. [10 marks]

Describe the potential impact on the strike in distance of:-

i) changing to 4 aspect signalling,
ii) automating the crossing clear function (e.g. using radar) as opposed to human surveillance via CCTV,
iii) a change to a cab signalling system. [6 marks]

There is a station 200m on the approach to the crossing at which 30% of trains stop. Describe how the system could be changed to minimise road closure time with a brief description of how the solution could be implemented. Describe how items i), ii) and iii) above could be affected by the solution. [9 marks]
23 Role of Control Centres

23.1 The signaller interface

When fixed signals were initially introduced on the railways, they were operated from the base of the signal. Concentrating the controls for signals and points in one place is more efficient and allows interlocking to be provided. The effort required to operate equipment via levers limits the area which can be controlled by mechanical interlockings. (Points require most effort and are restricted to 350 yards/320m maximum).

The development of power operation of points and signals allowed a larger area to be concentrated into a single signal box, replacing lever frames with diagrammatic control panels. Early panels used a separate switch for each item of equipment. Later route setting panels were developed with the signaller selecting the entrance and exit and the route selected, leaving the system to call all the required points into their desired positions.

The current generation of control centres contain VDU-based Signaller interfaces linked to Computer Based Interlockings (CBIs). Lineside equipment is controlled via telecoms links which allows equipment to be controlled from significant distances.

In the UK, Mainline's strategy is to control the entire mainline railway network (20,000 miles of track) from 12 "Rail Operating Centres" (ROCs).

Figure 23-1: Example of a signallers push button panel
Activity 23 a

Find out what is the preferred type/technology for a Signaller Interface on new projects on the railway you are most familiar with.

What other types of Signaller Interface are still in use?

Activity 23 b

Consider the advantages and disadvantages of a VDU-based Signaller Interface compared with a panel.

VDU-based signaller interfaces can provide a wide range of facilities to the signaller, including different display views, automatic route setting and error/fault reporting. While these can assist the signaller, it is necessary to assess whether the workload is appropriate under normal, abnormal and degraded conditions. More detail about Human Factors for signallers and drivers is part of the Module 7 Syllabus.

Activity 23 c

List the basic facilities that a signaller requires for a simple layout (indications, control functions, communications). Consider what other facilities are required (buildings, training etc).

What differences would there be for a large complex scheme such as a busy commuter terminus; think about the reasons for any differences.

23.2 Interlocking

The interlocking is the means by which Signalling Principles are applied to specific areas of railway. They are safety critical and form the core of a signalling scheme. In the UK, the main Interlocking technologies can be classified as:

- Electro-mechanical Interlocking;
- Route Relay Interlocking (RRI);
- Solid-state Interlocking (SSI) – see Chapter 2 of [8] and Chapter 6 of [9];
- Computer based Interlocking (CBI) – see Chapters 7 to 11 of [9].

All of the above interlocking types are adaptable to suit different railway layouts. The above interlocking types, with the exception of electro-mechanical, need not be located at the control centre. When the interlocking is at a remote location, it can be controlled over time-division multiplex (TDM) or frequency-division multiplex systems, or over a telecoms network using IP (Internet Protocol).

See Chapter 7 of [9] for an introduction to the generic principles and safety aspects of interlocking. Route control systems differ from earlier interlocking where each signal and point was controlled separately. Typically a route is set with 2 button pushes (entrance signal then exit signal), making the process simpler, especially in complex track layouts.

For an explanation of route setting and route holding refer to Section 14.
23.3 Detection and mitigation of overruns

Signalling systems must be designed to detect and react appropriately when drivers overrun (fail to stop at) stop signals. Various forms of train protection systems are used to mitigate SPADs (see Section 21).

The likelihood and consequences of overruns can be reduced by improving a layout with the help of risk modelling tools resulting in fewer unsafe overrun possibilities, and/or lower consequences. Calling of flank points can also reduce conflicts, but may also reduce operational flexibility.

Another mitigation is to detect overruns (either in the Signaller Interface or the interlocking) and reduce the consequences by replacing other signals in the area.

The more extensive the mitigation methods, the more complex the control tables, with associated increased difficulty in testing. Increased complexity can also increase the risk of errors in the design.

Activity 23 d
Examine a signalling plan for a complex junction and assess the potential for collisions if a train overruns. Could a different layout reduce the risks? What interlocking controls could provide mitigation? What would be the effects of these measures on traffic flow and flexibility? How would you justify implementation of these measures?

23.4 ARS logic/principles

Automatic Route Setting (ARS) systems can be used to operate main and shunt routes automatically as trains approach. Decision making logic is provided to enable the system to cope with minor disruption such as trains arriving out of the timetabled sequence. The signaller chooses whether to enable ARS or not over pre-defined areas under his control. See Chapter 8 of [8] for more information.

23.5 Traffic management

The UK Mainline's strategy for 12 ROCs has the intention that the human operator will rarely actually signal a train in real time, but will use conflict detection algorithms to make small changes in the precise scheduling of trains through junctions in an attempt to eliminate potential conflicts before they occur. The control system will then implement the solution and by using C-DAS (Connected Driver’s Advisory System) drivers will be influenced to amend their speed, perhaps coasting for a period to arrive at a junction at the optimum time rather than continue at full speed, encounter a restrictive aspect sequence and then stop, prior to needing to accelerate again.

23.6 Communications

There is a need for a signaller in a control centre to have good voice communications with many others, particularly during abnormal or degraded working. It is essential for responding effectively to emergency situations.

23.6.1 Radio communication to drivers.

A Cab Secure Radio system permits a driver to contact the signaller or vice versa without the delays and risks involved in using lineside phones.

On European mainline railways a common system GSM-R is being implemented.

Many metros use TETRA which can link with the public emergency services which is invaluable for dealing with major incidents.
There remains a role for telephone concentrators from which a signaller can rapidly receive or make a call to a particular phone with confidence that the call has been proved to be connected to the correct number. Driver radio has reduced the importance of having SPTs at every stop signal but many are still provided. The signaller may also require rapid communication with others such as:

- the controller of electric traction supply,
- the line / route controller,
- those responsible for employing the drivers and selling the train service to the public.

It is usual for all voice communication made to a control centre to be recorded; it not only provides invaluable evidence in the event of any incident, but regular reviews of recorded conversations can be used to monitor the standards of “Accuracy, Brevity and Clarity” being achieved and hence encourage the maintenance of high standards.

![Phone concentrator screen in the interlocking](image)

**Figure 23-5: Phone concentrator screen in the interlocking**

### 23.7 Train Describer (TD) facilities

Train describers originally developed as a means of communicating the identity of each train as it passed from one signaller’s area to another. As signalbox areas became larger, they became free-standing systems displaying on the track layout to a signaller the positions of all the trains currently under their control and those approaching the area. Where a VDU system is used for controlling trains, the train describer functionality is generally incorporated within the same display.

Signallers on the UK Mainline are now able to access such information for almost everywhere in the country; indeed some of this information is now available to the public (and can be more reliable than the information displayed on the Customer Information Screens at the station itself).

### Activity 23 e

Get a feel for the operation of a major station in very nearly “real time” by loading the appropriate map page from [www.opentraintimes.com](http://www.opentraintimes.com) (UK Mainline only).

Clicking on the train description for a particular train should display its actual running schedule compared to its timetabled path; however since the UK’s 4 digit form of TD means that certain codes are utilised more than once for different areas of the country, some of these results are “interesting”!

### 23.8 Past exam questions

**Question 23 A**

To improve operations on a railway it is proposed to introduce a system to automate route setting.

a) Describe the key inputs and outputs of such a system. [5 marks]
b) EITHER describe how the system could minimise delays on a mixed traffic railway (freight and passenger)

OR describe how the system could operate where several high density routes converge at an interchange. [10 marks]
c) One possible system works on a "first come, first served" basis. What might be the flaws with such a system and how could it be improved? [5 marks]
d) The system is a low integrity computer system. How could the total signalling system maintain safety? [5 marks]
## 24 Revision Record

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>06/05/2015</td>
<td>Outline with minimal content to illustrate concept</td>
</tr>
<tr>
<td>0.2</td>
<td>23/07/2015</td>
<td>Issued to other contributors FIO</td>
</tr>
<tr>
<td>0.3</td>
<td>27/10/2015</td>
<td>Issue to contributors for editing</td>
</tr>
<tr>
<td>0.4</td>
<td>27/11/2015</td>
<td>Issue for comments (Sections 10-13 and 20 not complete).</td>
</tr>
<tr>
<td>0.5</td>
<td>25/12/2015</td>
<td>First complete draft</td>
</tr>
<tr>
<td>0.6</td>
<td>16/03/2016</td>
<td>Final draft updated following examiner’s comments</td>
</tr>
<tr>
<td>0.7</td>
<td>22/04/2016</td>
<td>Final edit for format &amp; presentation</td>
</tr>
<tr>
<td>1.0</td>
<td>05/2016</td>
<td>Final formatting and convert to PDF for website</td>
</tr>
<tr>
<td>1.1</td>
<td>01/2017</td>
<td>Updates to sections 10, 11, 20 and minor updates throughout.</td>
</tr>
</tbody>
</table>
25 Authorship

The following authors and sources are acknowledged:

D. A. Pipet  Primary Author
Brian FitzGibbon  Author
Jason Lau  Author
Keith Upton  Author

Signet Solutions:  Some sections inspired by material from their AST course notes 2003, and particular thanks to Reuben Dakin for giving permission to use the diagrams from his Aspect Sequence handouts.
26 Feedback

The IRSE has revised this study guide following feedback from candidates but is always seeking continuous improvement and would welcome your views on how helpful this has been to you in preparing for the examination. It would be appreciated if you are able to take a few minutes to complete the feedback form below and send to the IRSE Professional Development Manager at 4th Floor 1 Birdcage Walk Westminster London SW1H 9JJ,UK or email pd@irse.org

<table>
<thead>
<tr>
<th>Overall do you think the Module 3 Study Guide has been helpful in your preparations for the exam?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ very helpful</td>
</tr>
</tbody>
</table>

If appropriate please briefly state areas where you would like to see improved

<table>
<thead>
<tr>
<th>Did you make use of the activities within the Study Guide?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ extensive use</td>
</tr>
</tbody>
</table>

If you used them, how helpful were the activities?

| □ very helpful | □ moderately helpful | □ only a little help | □ not helpful |

If appropriate please briefly state how the activities could be improved

<table>
<thead>
<tr>
<th>Did you make use of the reading references within the Study Guide and the Suggested Reading List?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ extensive use</td>
</tr>
</tbody>
</table>

If you used them, how helpful were the suggested reading references?

| □ very helpful | □ moderately helpful | □ only a little help | □ not helpful |

If appropriate please briefly state how the Suggested Reading List could be improved

<table>
<thead>
<tr>
<th>Did you make use of the exam questions within the study guide?</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ extensive use</td>
</tr>
</tbody>
</table>

If you used them, how helpful were the past exam questions within the Study Guide?

| □ very helpful | □ moderately helpful | □ only a little help | □ not helpful |

If appropriate please briefly state how the past exam questions could be improved

Finally if you have used other study guides for other IRSE modules we would appreciate your comments on how the study guide for module 3 compares with them
27 Bibliography