T Level Technical Qualification in Agriculture, Land Management and Production (Level 3)

Theory Exam Paper 2: Land-based engineering Core Pathway

Sample mark scheme

September 2023 v2.1

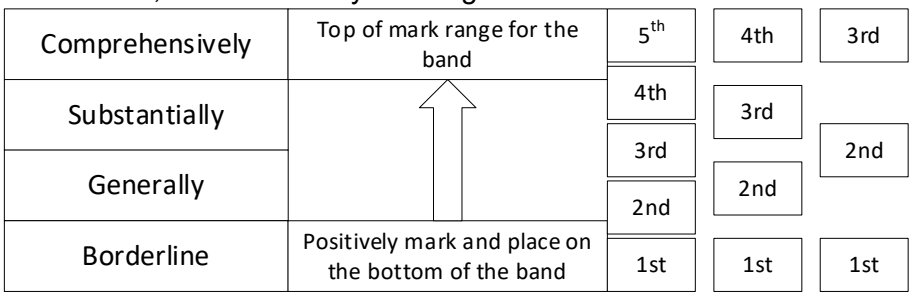
Marker guidance

Unless otherwise stated in the marker guidance for a specific question, the following conventions apply:

- All marking, from start to finish must be consistent and in line with the mark scheme guidance. Continue to refer to the mark scheme throughout marking.
- For questions that ask for a specific number of points, accept the first answers given up to the number requested eg State three… only accept the first three answers listed, and disregard any additional answers provided.
- For questions requiring continuous prose answers, mark positively – all correct answers should receive the appropriate mark according to the mark scheme. Any wrong (**but neutral**) answers should be ignored, and no marks should be lost.
- In some circumstances, it is appropriate to disallow a candidate answer that initially appears to give the correct answer as given in the mark scheme, if it is undermined by the fact that it goes on to actively **contradict** its intention. Sometimes the minimal wording used in the mark scheme allows a match that in reality is trivial and it is clear the candidate is referring to the wrong knowledge/understanding. Only the part of the response to which the contradiction applies should be disallowed, not the whole response. Material that is irrelevant/neutral but not contradictory should be ignored and positive marking applied as above.
- Use the full range of marks for a question as described by the mark scheme – eg for a 2-mark question, 0, 1 or 2 marks will always be available to award (never just 0 or 2). For levels marking, the full range of marks should be used freely as described by the mark scheme including 0 and full marks.
- Always award whole marks; half marks cannot be awarded.
- Allow phonetic misspellings as long as the meaning is clear, ie not so similar to another relevant but wrong term that you have to guess which was intended.
- Only allow 'it' as reference to the question topic if it is clear what 'it' refers to.
- Mark crossed out work **unless** it has been replaced by another response.
- Where judgement is required, apply the guidance. Where the guidance does not sufficiently support for a particular candidate response/interpretation, contact your Team Lead.
- Accept alternative wording that reflects what is given in the mark scheme.
- Contact your Team Lead if any additional correct answers arise which need to be added to the mark scheme.
- For level of response mark schemes:

  Note: indicative content has been provided to help orient the marking, providing a sense of the intentions of the question and expected parameters of the response. It is not exhaustive, and candidates do not need to cover all points referenced. Candidates may provide good quality responses while taking an approach which legitimately focuses either on breadth or depth given the time constraints. While the best responses are more likely to go to some depth across a broader range, there will be acceptable variation. Any pointers in the question towards coverage eg '…a range of…' should be kept in mind and balanced, through professional judgement, as to how much this affects the overall quality of the response when applying the marking instructions.

- First, read the full candidate response and decide which band descriptor best fits the overall level of quality of the response, in the context of the indicative content.
- Then, to decide on a mark within the band, consider the ***degree to which*** **the response fits the criteria**, as indicated by the diagram below:



The table below provides further detail on the descriptors used within each of the mark bands and what is expected at each level. Use the descriptors below alongside the mark scheme to support accurate and consistent judgment of candidate's response and allocation of marks.

AO2	**AO3**
Basic	
Limited understanding that is relevant to the context or question. Limited accuracy in interpretation through lack of application of relevant knowledge and understanding.	Limited accuracy in analysis through lack of application of relevant knowledge and understanding. Unsupported evaluation through lack of application of knowledge and understanding. Unsupported judgement through lack of application of knowledge and understanding.
Good	
Some understanding that is relevant to the context or question. Some accuracy in interpretation through the application of some relevant knowledge and understanding.	Some accuracy in analysis through the application of some relevant knowledge and understanding. Partially supported evaluation through the application of some relevant knowledge and understanding. Partially supported judgement through the application of some relevant knowledge and understanding.
Thorough	
A range of accurate understanding that is relevant to the context or question. Accurate interpretation through the application of relevant knowledge and understanding.	Accurate analysis through the application of relevant knowledge and understanding. Supported evaluation through the application of relevant knowledge and understanding. Supported judgement through the application of relevant knowledge and understanding.
Comprehensive	
A range of detailed and accurate understanding that is fully relevant to the context or question. Detailed and accurate interpretation through the application of relevant knowledge and understanding.	Detailed and accurate analysis through the application of relevant knowledge and understanding. Detailed and substantiated evaluation through the application of relevant knowledge and understanding. Detailed and substantiated judgement through the application of relevant knowledge and understanding.

This exam has been split into **two** sections.

Below details the types of questions and marks available for each section. Please allow time for each section accordingly.

Section A is made up of **44** marks and includes **15** short answer and medium answer questions.
Section B is made up of **36** marks and includes **3** extended response questions.

Assessment Objectives	Mark allocation
AO1a Demonstrate knowledge The ability to demonstrate recall of relevant knowledge in response to straightforward questioning.	**10%**
AO1b Demonstrate understanding The ability to explain principles and concepts beyond recall of definitions, but in a general way – ie out of a particular context in response to straightforward questioning.	**15%**
AO2 Apply knowledge and understanding to different situations and contexts Using and applying knowledge and understanding, taking the understanding of generalities and applying them to specific situations. Questions are likely to ask for application in relation to a straightforward situation.	**45%**
AO3a Analyse information and issues Complex thinking that distinguishes patterns and relationships, breaking material into constituent parts, and determining how the parts are related to one another and holistically, inferring underlying assumptions/conditions /relevance/causation.	**30%**
AO3b Evaluate information and issues The ability to make judgements about the value, for some purpose, of own or others' work/ideas/solutions/methods using internal or external criteria or standards relevant for the occupational area. These criteria may include eg quality, accuracy, effectiveness, efficiency, coherence, consistency, and may be quantitative or qualitative.	

Section A

Q1	Recycling is one of the principles of waste management. a) Name **one** other principle. (1 mark) b) What does COSHH stand for? (1 mark)	
Mark Scheme	**Part a)** • Refuse (1) • Reuse (1) • Reduce (1) • Repurpose (1) **Part b**) • Control of Substances Hazardous to Health	**Marking guidance** a) Award **1 mark** for **one other** correct principle. b) Award **1 mark** for the correct wording.
Total marks	2	
AO	AO1a	
Qual spec reference	2.2 Waste management principles.	

Q2	Labour, parts and sundries/consumables are the main components of an invoice for a machinery service. Identify **two** different examples of other individual costs. (2 marks)	
Mark Scheme	• Credit charge (1) • Environmental/disposal surcharges (1) • Value added tax (1) • Travel (1) • Collection and delivery costs (1)	**Marking guidance** Award **1 mark** for each correct example up to a maximum of **2 marks**. Credit any other appropriate response.
Total marks	2	
AO	AO1a	
Qual spec reference	8.2 Costs associated with land-based engineering operations.	

Q3	List the **first two** control measures in the hierarchy of hazard control. (2 marks)	
Mark Scheme	• Elimination (1) • Substitution (1)	**Marking guidance** Award **1 mark** for each correct control measure up to a maximum of **2 marks**. An example of a control measure is acceptable.
Total marks	2	
AO	AO1a	
Qual spec reference	1.1 Hazards, risks and control measures associated with working in the land-based engineering sector.	

Q4	Describe the requirements for the disposal of hazardous waste. (2 marks)	
Mark Scheme	• Through a waste disposal company that must comply with legislation (1) and must provide a record of the disposal (1) • Through a waste disposal company that must comply with Controlled Waste Regulations (1) and must provide an audit trail of the disposal (1)	**Marking guidance** Award **1 mark** for each requirement up to a maximum of **2 marks**. Credit any other appropriate response.
Total marks	2	
AO	AO1a	
Qual spec reference	2.2 Waste management principles.	

Q5	Explain **one** reason why it is important to use mechanical supports when lifting with a hydraulic jack. (2 marks)	
Mark Scheme	• To prevent injury/death by crushing (1) because the hydraulic jack is not a rigid support (1) • The mechanical support is a control measure (1) for the risk of the hydraulic jack failing (1)	**Marking guidance** Award **1 mark** for a basic explanation, and award **1 further mark** for a developed explanation to a maximum of **2 marks**. Award a maximum of **2 marks** for **one** reason that is fully explained. Credit any other appropriate response.
Total marks	2	
AO	AO1b	
Qual spec reference	1.1 Hazards, risks and control measures associated with working in the land-based engineering sector.	

Q6	Give **two** examples of how stock levels are managed to meet seasonal demand. (2 marks)	
Mark Scheme	• Early ordering in anticipation of seasonal needs (1) • Review historic/sales data to predict demand (1) • Out of season/pre-season marketing campaign to prompt early customer ordering (1) • Use 'overnight/24hr/VOR' delivery instead of stocking high value/slow moving/non-stock items (1)	**Marking guidance** Award **1 mark** for each correct example up to a maximum of **2 marks**. Credit any other appropriate response.
Total marks	2	
AO	AO1b	
Qual spec reference	4.2 Principles of stock management.	

Q7	Explain why a customer may prefer a quotation instead of an estimate. (2 marks)	
Mark Scheme	• A quotation is a fixed price valid for a fixed period whereas an estimate is a guide price which can vary (1) so the customer can budget costs more accurately from a quotation (1) • A quotation is a fixed price valid for a fixed period whereas an estimate is a guide price which can vary (1) so the customer can accurately compare costs to other companies (1)	**Marking guidance** Award **1 mark** for a basic explanation, and award **1 further mark** for a developed explanation, to a maximum of **2 marks**. Award a maximum of **2 marks** for **one** reason that is fully explained. Credit any other appropriate response.
Total marks	2	
AO	AO1b	
Qual spec reference	8.2 Costs associated with land-based engineering operations.	

Q8	a) Explain **one** example of disruption to the supply chain caused by political external influences. (2 marks) b) Explain **one** example of disruption to the supply chain caused by environmental external influences. (2 marks)	
Mark Scheme	**Part a)** • Country to country hostility causes trade restrictions (1) which leads to product shortage (1) • International law sets trade sanctions which stops movement of money/goods (1) leading to higher prices (1) **Part b)** • Natural disaster limits availability of raw materials (1) which leads to limited manufacture of products (1) • Natural disaster causes destruction of factories (1) which stops manufacturing (1)	**Marking guidance** Award **1 mark** for each basic explanation, and award **1 further mark** for each developed explanation, to a maximum of **2 marks**. Award a maximum of **4 marks** for **two** examples that are fully explained. Credit any other appropriate response.
Total marks	4	
AO	AO1b	
Qual spec reference	4.1 The supply chain.	

Q9	State the Ohms law formula used to calculate electrical resistance. (1 mark)	
Mark Scheme	• Volts ÷ Amperes = Ohms (1) • **or** R=V ÷ I (1)	**Marking guidance** Award **1 mark** for the correct formula.
Total marks	1	
AO	AO1b	
Qual spec reference	6.10 Scientific laws used in land-based engineering.	

Q10	Each cylinder within a four-cylinder compression ignition engine has a bore of 105 millimetres (mm) and a stroke of 127 millimetres (mm). a) State the formula used to calculate the capacity of a cylinder. (1 mark) b) Calculate the capacity of **one** cylinder to the nearest cubic centimetre (cc). (2 marks)	
Mark Scheme	**Part a)** • Volume = $\pi r^2 h$ (1) **Part b)** • 3.142 × 5.25 × 5.25 × 12.7 (1) = 1099.8374625 • 1100cc (1) Use of a calculator is permitted.	**Marking guidance** **a)** Award **1 mark** for the correct formula. **b)** Award **1 mark** for demonstration of correct methodology. Award **1 mark** for the correct answer. Answer based on π as 3.142, but allow reasonable variations eg 3.14 or 22/7
Total marks	3	
AO	AO1b – 1 AO2 – 2	
Qual spec reference	6.10 Scientific laws used in land-based engineering.	

<table>
<tr><td>Q11</td><td colspan="2">There has been an outbreak of a notifiable disease in the poultry industry.

A customer from this industry, who is not currently affected, requires some repairs to be made to their materials handler which is used to transport the poultry food.

Explain two contamination control measures which a technician would follow in order to manage the risks of the notifiable disease.

(4 marks)</td></tr>
<tr><td>Mark Scheme</td><td>• Follow the customer’s disinfection procedure on entering the premises to destroy potential contaminants (1) to prevent introduction of the disease from outside (1)

• On arrival wear PPE which is appropriately approved so that it is current (1) which will be effective in reducing the risk of the technician transferring the disease into the facility (1)

• Ensure poultry are not in the repair area so the technician is separated from them (1) to minimise their potential exposure to the disease (1)

• Ensure that the materials handler work area is isolated to limit the technician’s contact within the site (1) to reduce the potential for transfer through contaminated machinery (1)

• Securely dispose of used PPE on site so that possible contamination is contained (1) reducing the risk of transfer (1)</td><td>Marking guidance

Award 1 mark for each basic explanation, and 1 further mark for each developed explanation, to a maximum of 2 marks.

Award a maximum of 4 marks for two control measures that are fully explained.

Credit any other appropriate response.</td></tr>
<tr><td>Total marks</td><td colspan="2">4</td></tr>
<tr><td>AO</td><td colspan="2">AO2</td></tr>
<tr><td>Qual spec reference</td><td colspan="2">3.1 Biosecurity requirements and organisational policies.</td></tr>
</table>

<table>
<tr><td>Q12</td><td colspan="2">A granular fertiliser spreader’s ferrous metal component has seized with age.

a) Explain what has happened to cause the seizure of the ferrous metal component.
(3 marks)

b) Give one action that could be taken to prevent another seizure due to the same cause.
(1 mark)</td></tr>
<tr><td>Mark Scheme</td><td>Part a)
• Ferrous metal is subject to oxidisation caused by a chemical reaction with the fertiliser. (1) Deterioration/ wear of the component’s protective coatings over time will allow surface damage from the oxidisation (1) which increases friction between moving components leading to the seizure. (1)

Part b)
• Post-use cleaning to remove residual fertiliser (1)
• Refresh protective coating on ferrous metal to prevent oxidisation/corrosion (1)
• Replacing component with a non-ferrous material which will not react to the fertiliser (1)</td><td>Marking guidance
a) Award 1 mark for a basic explanation, and award up to 2 further marks for a developed explanation, to a maximum of 3 marks.

Award a maximum of 3 marks for one explanation.

Credit any other appropriate response.

b) Award 1 mark for a correct action which will prevent another seizure due to the same cause.

Credit any other appropriate response.</td></tr>
<tr><td>Total marks</td><td colspan="2">4</td></tr>
<tr><td>AO</td><td colspan="2">AO2</td></tr>
<tr><td>Qual spec reference</td><td colspan="2">7.1 Causes, effect, and prevention of corrosion.</td></tr>
</table>

Q13	A diesel exhaust fluid (DEF) injector is used to reduce emissions in a machine's compression ignition engine. A faulty software update has caused the diesel exhaust fluid injector to fail. Explain **two** consequences of the DEF injector failure for a machine. (4 marks)	
Mark Scheme	• Emissions would cause environmental pollution because the NOx is not being converted (1) which increases the amount of poisonous gases released into the environment from the exhaust system (1) • There would be a reduction in engine power when the machine enters a restricted/limp-home mode (1) because system sensors detect a reduction of DEF (1) • The engine software will need recalibration after the injector repair so that the emissions control system operates correctly (1) so the relevant emissions legislation are met (1)	**Marking guidance** Award **1 mark** for each basic explanation, and award **1 further mark** for each developed explanation, to a maximum of **2 marks**. Award a maximum of **4 marks** for **two** consequences that are fully explained. Credit any other appropriate response.
Total marks	4	
AO	AO2	
Qual spec reference	6.1 Operating principles of power units and associated integrated and stand-alone systems.	

Q14	Explain **two** reasons why a hydrostatic power transmission system is used instead of a mechanical power transmission system on a rough-terrain material handler. (4 marks)	
Mark Scheme	• The flow of fluid in a hydrostatic power transmission system enables infinitely variable speed of operation (1) which allows slower speed driving for more precise movement of the materials handler (1) • A hydrostatic system can be located in any position because of the hoses/connections between components (1) so the hydrostatic system can be elevated and protected from the terrain (1) • A hydrostatic system is simpler to operate because changes of forward to reverse direction are more efficient (1) which is more suited to operation of a materials handler (1) • A hydrostatic power transmission is a simpler design with fewer moving parts exposed to the environment (1) which results in less maintenance (1)	**Marking guidance** Award **1 mark** for each basic explanation, and award **1 further mark** for each developed explanation, to a maximum of **2 marks**. Award a maximum of **4 marks** for **two** reasons that are fully explained. Credit any other appropriate response.
Total marks	4	
AO	AO2	
Qual spec reference	6.2 Operating principles of gearboxes, transmissions, and drivelines, and associated sub-assemblies, components and traction. 6.3 Operating principles of hydraulic systems and components.	

<table>
<tr><td>Q15</td><td>A land-based engineering company has recently recruited three new staff, taking the total number of staff to seven.

Explain the implications of the increase in staff numbers on the employer’s responsibilities under the Management of Health and Safety at Work Regulation 1999.
(6 marks)</td></tr>
<tr><td>Mark Scheme</td><td>
<table>
<tr><th>Band</th><th>Marks</th><th>Descriptor</th></tr>
<tr><td>3</td><td>5-6</td><td>Demonstrates thorough application of knowledge and understanding of implications of increase in staff numbers on employer responsibilities under the regulation.
Reasoning for the implications is highly detailed and relevant.</td></tr>
<tr><td>2</td><td>3-4</td><td>Demonstrates good application of knowledge and understanding of implications of increase in staff numbers on employer responsibilities under the regulation.
Reasoning for the implications is mostly detailed and relevant.</td></tr>
<tr><td>1</td><td>1-2</td><td>Demonstrates basic application of knowledge and understanding of implications of increase in staff numbers on employer responsibilities under the regulation.
Reasoning for the implications has limited detail and relevance.</td></tr>
<tr><td></td><td>0</td><td>No relevant material</td></tr>
</table>
Indicative content:
• The number of employed staff has increased beyond five so the employer has additional responsibilities under this Act.
• A member of staff must be appointed as the ‘competent person’ responsible for health and safety to carry out an audit of the procedures within the company.
• The risk assessments produced from the audit will identify the hazards and how to minimise the risks using control measures and appropriate training.
• The employer must display health and safety information/signage.
• The employer must have a written health and safety policy.
• Emergency procedures must be in place for situations such as accidents and fires.
• The employer must review risk assessments if there is a material change.
• If the employer does not implement the additional responsibilities, they are liable for prosecution.
</td></tr>
<tr><td>Total marks</td><td>6</td></tr>
<tr><td>AO</td><td>AO2</td></tr>
<tr><td>Qual spec reference</td><td>1.3 Specific health and safety legislation in land-based engineering.</td></tr>
</table>

Section B

Q16	A customer has a telescopic handler with a liquid cooled diesel engine. The customer reports that the cooling system overheats under normal working conditions. A senior technician has carried out daily operator checks, including checking coolant level, fan belt tension, and the air flow through the radiator. They have identified that there is a faulty component within the cooling system. Analyse how the operation of the components could cause the cooling system to overheat and justify any tests of conformity. (12 marks)

Band	Marks	Descriptor
4	**10-12**	Demonstrates comprehensive application of knowledge and understanding of the operating principles of the machinery, cooling system and its components, and tests of conformity in relation to the possible causes of the cooling system overheating. Demonstrates comprehensive use of analysis of how the operation of the components could cause the cooling system to overheat in relation to the operating principles of the components. Demonstrates comprehensive evaluative skills by justifying an excellent range of tests to assess conformity. Justifications are supported with highly detailed and relevant reasoning.
3	**7-9**	Demonstrates thorough application of knowledge and understanding of the operating principles of the machinery, cooling system and its components, and tests of conformity in relation to the possible causes of the cooling system overheating. Demonstrates thorough use of analysis of how the operation of the components could cause the cooling system to overheat in relation to the operating principles of the components. Demonstrates thorough evaluative skills by justifying a good range of tests to assess conformity. Justifications are supported with mostly detailed and relevant reasoning.
2	**4-6**	Demonstrates good application of knowledge and understanding of the operating principles of the machinery, cooling system and its components, and tests of conformity in relation to the possible causes of the cooling system overheating. Demonstrates good use of analysis of how the operation of the components could cause the cooling system to overheat in relation to the operating principles of the components. Demonstrates good evaluative skills by justifying a moderate range of tests to assess conformity. Justifications are supported with some detail and relevant reasoning.

1	**1-3**	Demonstrates basic application of knowledge and understanding of the operating principles of the machinery, cooling system and its components, and tests of conformity in relation to the possible causes of the cooling system overheating. Demonstrates basic use of analysis of how the operation of the components could cause the cooling system to overheat in relation to the operating principles of the components. Demonstrates basic evaluative skills by justifying a limited range of tests to assess conformity. Justifications are supported with minimal detail and relevant reasoning.
	0	**No relevant material**

Indicative content:

Analysis
Components: what can go wrong to cause the cooling system to overheat

- Thermostat: regulates engine temperature to ensure fast warm up, less engine wear and better fuel efficiency. Partial opening or stuck closed leads to overheating due to reduced coolant flow. Scenario implies that there could be a faulty thermostat
- Radiator/system pressure cap: allows coolant to operate approximately 8-10°C above boiling point to permit efficient engine operation. Faulty cap would cause loss of coolant and system pressure, resulting in overheating. Scenario implies that there could be a faulty radiator cap.
- Coolant/water pump: moving component that circulates liquid coolant around the cooling system to allow faster heat removal, maintaining a consistent engine temperature. Seals and/or bearings can fail leading to external leaks or failure of the pump, leading to reduced cooling efficiency. Scenario implies that there could be a faulty pump.
- Hoses, radiator core, heater pipes, heater matrix, engine block: liquid coolant flows through these components to enable transfer of heat via the radiator, which cools the engine. These are locations for potential internal and external leaks leading to a reduced amount of coolant, which causes overheating. Scenario implies that there could be a coolant leak.
- Fan: mechanical component, draws air though the radiator to reduce coolant temperature. Running too slow, not running at all, or there are damaged/missing fan blades the air flow is reduced. Poor air flow through the radiator causes overheating. Scenario implies that there could be a fault with the fan operation.
- Thermo-viscous fan coupling: hydraulic component, operates at reduced engine speed to allow rapid warm up of the engine, speed of fan increases as engine temperature rises. Helps accurately control coolant temperature by removing excess heat from the radiator. Moving component could fail, leading to it running too slowly and resulting in engine overheating. Scenario implies that the coupling could have failed.
- Electro-fan: temperature sensor controlled, electronic engaged, allows rapid warm up and engages as engine temperature rises. Failure of the electric motor powering the fan could cause it to run too slowly or stop, resulting in engine overheating. Scenario implies that the electrically powered fan could have failed.

Justification
Tests of conformity to identify the component(s) that could cause the cooling system to overheat

	• Pressure test cooling system: an effective and efficient test because it assesses a wide range of cooling system components which can fail:
	  o Pressurise system to achieve manufacturer's operating pressure. This pressure should be maintained; if pressure drops this indicates a system leak which could be external or internal.
	  • External leaks: undertake a visual inspection to determine location of leak (components checked: hoses, pipes, radiator, heater matrix, coolant/water pump eg stains on the pump housing, engine block core plugs, cylinder head core plugs).
	  • Internal leaks: run engine with pressure tester connected – pressure should rise slowly. If a rapid rise in the pressure the cooling system is being pressurized by combustion gases. Readings may suggest inspection of head-gasket or cracked block. (components checked: engine block).
	• Fan Test: only method to check that the fan is turning and that the air flow through the radiator is constant and dissipates the heat:
	  o Visual observation of mechanical fan and fan cowling for damage, and of fan speed relative to engine speed.
	• Electro-fan test: to check that the electric fan motor is operating to specification and the integrity of the wiring system; visual check is quick; the diagnostic test will provide an accurate speed reading.
	• Thermo-viscous coupling test: the only method to check if the coupling is working:
	  o Visual observation of the coupling to assess fan speed in relation to engine speed.
	• Radiator/system pressure cap test: the only method to test radiator/system cap's ability to raise the boiling point of the coolant:
	  o Connect to pressure tester, pressure gauge should read the pressure marked on the cap. If not, damaged seal/spring or vacuum valve.
	• Thermostat testing: the only method to assess the thermostat operation, a fundamental test because this is one of the few moving components, so it can fail due to wear and tear:
	  o To test full opening and closing ability to ensure rapid engine temperature rise on start-up and constant operating temperature whilst running: remove the thermostat, insert in water, raise the water temperature, monitor at what temperature it opens as water is heated up.
	
	Credit any other appropriate response.

Total marks	12
AO	AO2 – 4 marks AO3a – 4 marks AO3b – 4 marks
Qual spec reference	5.1 Types of land-based equipment and machinery. 6.1 Operating principles of power units and associated integrated and stand-alone systems.

Q17	A self-propelled ride-on mower is fitted with a traditional lead acid battery and solenoid pre-engaged starter motor. The starter motor operates slowly and will not start the engine. The engine and the cold start mechanism operate correctly. A senior technician has carried out the recommended operator checks and confirmed that the charging system and other electrical circuits are functioning correctly. They have identified that there is a faulty component within the starting system. Analyse how the operation of the components could cause the starting system to malfunction and justify any tests of conformity. (12 marks)

Band	Marks	Descriptor
4	**10-12**	Demonstrates comprehensive application of knowledge and understanding of the operating principles of the machinery, starting system and its components, and tests of conformity in relation to the possible causes of the starting system malfunction. Demonstrates comprehensive use of analysis of how the operation of the components could cause the starting system to malfunction in relation to the operating principles of the components. Demonstrates comprehensive evaluative skills by justifying an excellent range of tests to assess conformity. Justifications are supported with highly detailed and relevant reasoning.
3	**7-9**	Demonstrates thorough application of knowledge and understanding of the operating principles of the machinery, starting system and its components, and tests of conformity in relation to the possible causes of the starting system malfunction. Demonstrates thorough use of analysis of how the operation of the components could cause the starting system to malfunction in relation to the operating principles of the components. Demonstrates thorough evaluative skills by justifying a good range of tests to assess conformity. Justifications are supported with mostly detailed and relevant reasoning.
2	**4-6**	Demonstrates good application of knowledge and understanding of the operating principles of the machinery, starting system and its components, and tests of conformity in relation to the possible causes of the starting system malfunction. Demonstrates good use of analysis of how the operation of the components could cause the starting system to malfunction in relation to the operating principles of components. Demonstrates good evaluative skills by justifying a moderate range of tests to assess conformity. Justifications are supported with some detail and relevant reasoning.

1	**1-3**	Demonstrates basic application of knowledge and understanding of the operating principles of the machinery, starting system and its components, and tests of conformity in relation to the possible causes of the starting system malfunction. Demonstrates basic use of analysis of how the operation of the components could cause the starting system to malfunction in relation to the operating principles of the components. Demonstrates basic evaluative skills by justifying a limited range of tests to assess conformity. Justifications are supported with minimal detail and relevant reasoning.
	0	**No relevant material**

Indicative content:

Analysis

Components: what can go wrong to cause the starting system to malfunction (starter motor operates slowly)

- Battery: uses a chemical reaction between the lead plates and electrolyte to store electrical energy to power the starter motor. Faulty chemical reaction or an internal short circuit will result in a low specific gravity within the battery, so insufficient power to the starter motor eg weak cell could cause a faulty chemical reaction. Scenario implies that the battery could be faulty.
- Ignition switch: provides battery voltage to the starter motor solenoid exciter terminal. Worn internal connections (high resistance) stop current reaching the solenoid. Potentially total failure or intermittent fault. Scenario implies that the ignition switch could be at fault.
- Safety switches: provides a breakable connection between the ignition switch and starter motor solenoid exciter terminal, so that the engine cannot be started in an unsafe way. Worn switch connections (high resistance) stop current reaching the starter motor solenoid. Potentially total failure or be intermittent fault. Scenario implies that safety switches could be at fault.
- Starting system starter motor: uses electromagnets, armature and brushes; it converts electrical voltage into a turning torque to rotate the engine. Where corrosion/wear of internal commutator and brushes, or open/short circuits occur this can lead to low starter motor speed/torque. This would result in reduced cranking speed. Scenario implies that the starting system starter motor could be at fault.
- Starting system electrical connections: transmit power from the battery to the solenoid exciter circuit via the ignition and safety switches, and from the battery to the starter motor via its solenoid. Loose, corroded or damaged connections create high resistance and loss of voltage to the solenoid and starter motor, leading to low speed/torque of the starter motor, resulting in reduced cranking speed. Scenario implies that the electrical connections could be faulty.
- Starting system solenoid: uses voltage to operate an internal electromagnet to engage the starter motor with the flywheel ring gear and make the contact between battery live terminal (high amperage) and starter motor connection to power the motor. Damage to solenoid windings, loose, corroded, or damaged connections, creates high resistance and loss of power to the starter motor, leading to starter motor failure, or low cranking speed. Scenario implies that the starting system solenoid could be faulty.
- Relays: allow a low current to operate a high current circuit. Internal fault or poor connections can result in failure to switch the starter system circuits on and off. Scenario implies that the relays could be faulty.

	Justification
	Tests of conformity to identify the component(s) that could cause the starting system to malfunction
	• Battery:
	  o Test using hydrometer/refractometer: effective and most accurate method to check the condition of the battery, assesses individual battery cells.
	  ▪ Compare specific gravity readings to manufacturer's specification; reading could indicate that the battery needs charging or has a faulty cell/cells (battery needs replacing).
	  o Heavy duty discharge test: efficient (quick) and accurate test; safer than hydrometer because no potential contact with battery acid, and assesses internal battery connections which the hydrometer does not do:
	  ▪ Simulates the starter circuit's draw on battery power: result should meet manufacturer's specification.
	• Safety and ignition switches: only method to check these components are serviceable:
	  o Check electrical continuity meets manufacturer's specification. If below the specification it indicates internal switch fault.
	• Measure voltage at solenoid exciter terminal at cranking with a multimeter: quick to perform method to check the integrity of the solenoid exciter circuit providing a sufficiently accurate diagnosis:
	  o Result should meet manufacturer's specification. If below the specification it indicates poor connections in wiring or ignition/safety switches.
	• Measure voltage drop across solenoid terminals at cranking with a multimeter: quick to perform method to check the integrity of the solenoid providing a sufficiently accurate diagnosis:
	  o Result should meet manufacturer's specification. If below the specification it indicates faulty solenoid internal connections or poor external connections.
	• Measure voltage at starter motor input terminal at cranking with a multimeter: quick to perform method to check the integrity of the circuit providing a sufficiently accurate diagnosis:
	  o Result should meet manufacturer's specification. If below the specification it indicates high resistance in the connections.
	• Measure voltage drop in the insulated line at cranking with a multimeter: quick to perform method to check the integrity of the insulated line providing a sufficiently accurate diagnosis:
	  o Result should meet manufacturer's specification. If above the specification it indicates poor connections/high resistance in the insulated circuit.
	• Measure voltage drop in earth line at cranking with a multimeter: quick to perform method to check the integrity of the earth line providing a sufficiently accurate diagnosis:
	  o Result should meet manufacturer's specification. If above the specification it indicates poor connections/high resistance in the earth circuit, including battery and earth straps.
	
	Credit any other appropriate response.

Total marks	12
AO	AO2 – 4 marks AO3a – 4 marks AO3b – 4 marks
Qual spec reference	5.1 Types of land-based equipment and machinery. 6.4 Operating principles of electric/electronic systems and components.

Q18	On a 3.6 Litre multi-cylinder compression ignition engine powered generator, a customer reports that the engine oil pressure light flickers at lower engine speeds when at operating temperature. The engine has 8,000 hours of operation. A senior technician has carried out an initial investigation and confirmed that the engine had been serviced to the manufacturer's specification, and the correct engine running speeds have been set. Analyse how faulty operation of the engine components would cause the engine oil pressure light to flicker and justify any tests of conformity. (12 marks)

Band	Marks	Descriptor
4	**10-12**	Demonstrates comprehensive application of knowledge and understanding of the operating principles of the multi-cylinder compression ignition engine and its components, and tests of conformity in relation to the possible causes of the engine oil pressure light flicker. Demonstrates comprehensive use of analysis of how the operation of the components could cause the engine oil pressure light to flicker in relation to the operating principles of the components. Demonstrates comprehensive evaluative skills by justifying an excellent range of tests to assess conformity. Justifications are supported with highly detailed and relevant reasoning.
3	**7-9**	Demonstrates thorough application of knowledge and understanding of the operating principles of the multi-cylinder compression ignition engine and its components, and tests of conformity in relation to the possible causes of the engine oil pressure light flicker. Demonstrates thorough use of analysis of how the operation of the components could cause the engine oil pressure light to flicker in relation to the operating principles of the components. Demonstrates thorough evaluative skills by justifying a good range of tests to assess conformity. Justifications are supported with mostly detailed and relevant reasoning.
2	**4-6**	Demonstrates good application of knowledge and understanding of the operating principles of the multi-cylinder compression ignition engine and its components, and tests of conformity in relation to the possible causes of the engine oil pressure light flicker. Demonstrates good use of analysis of how the operation of the components could cause the engine oil pressure light to flicker in relation to the operating principles of the components. Demonstrates good evaluative skills by justifying a moderate range of tests to assess conformity. Justifications are supported with some detail and relevant reasoning.

1	**1-3**	Demonstrates basic application of knowledge and understanding of the operating principles of the multi-cylinder compression ignition engine and its components, and tests of conformity in relation to the possible causes of the engine oil pressure light flicker. Demonstrates basic use of analysis of how the operation of the components could cause the engine oil pressure light to flicker in relation to the operating principles of the components. Demonstrates basic evaluative skills by justifying a limited range of tests to assess conformity. Justifications are supported with minimal detail and relevant reasoning.
	0	**No relevant material**

Indicative content:

Analysis

Components: what can go wrong to cause the engine oil pressure warning light to flicker

Low oil pressure will cause the warning light to flicker. Scenario implies that any of the following components could be causing this:

Electrical: not impacted by engine speed:

- Wiring: sends and receives voltage to the warning light. Damaged or short circuit causes earthing of the switch (single pin) and the light to flicker.
- Switch: correct oil pressure pushes on the internal diaphragm and opens the contacts (open circuit), and the warning light goes out. If internal damage, contamination, the switch short circuits and light comes on.
- Transducer: measures oil pressure and converts to a voltage (2 or 3 pin switch) to send to electronic control unit (ECU) as input signal and output to the warning light. It may have a numerical figure displayed. Internal fault of the transducer or wiring (as above) causes too low a return voltage to ECU, therefore no output to warning light.

Mechanical: impacted by engine speed:

- Oil pump: driven from the crankshaft and draws oil from the sump through a strainer, the restrictions in the engine produce oil pressure.
    - Intermittent drive from crankshaft: pump speed low leading to low pressure.
    - Worn pump internals, stuck open pressure relief valve (PRV), blocked oil strainer in sump: reduction in oil flow/pressure especially at low engine speeds (idle). Cracked oil pick up pipe.

Engine: impacted by engine speed:

- Oil from the pump flows through the oil filter into the main oil gallery and splits to feed pressure to the crankshaft and main/big end bearings, camshaft and balancer bushes, timing gears and cylinder head.
    - Excessive bearing or bush clearance cause less oil restriction and hence lower oil pressure.

Liquid:

- The engine oil is used to lubricate engine parts, clean, cool and hold contaminants in suspension. Its viscosity (SAE rating) and specification (API or ACEA) is related to the engine application, its engine type, working and service conditions.
    - Engine operating temperature/ load too high leads to oil viscosity being low (thinned) and reduced pressure.

	○ Fuel dilution (contamination by fuel): Injectors faulty, injector seals leaking, incorrect timing, leaking fuel injection or feed pump, internal common rail leak. Reduces oil viscosity (incorrect) and reduced pressure. ○ Coolant dilution (contamination by coolant): oil cooler, liner, block, or cylinder head cracked, or head gasket damaged. Internal leak of coolant into the oil. Reduces oil viscosity (incorrect) and reduced pressure. **Justification** Tests of conformity to identify the component(s) that could cause the engine oil pressure warning light to flicker • If the wiring, switch, or transducer are faulty it will indicate low oil pressure on the pressure gauge (warning light flicker) even when the oil pressure meets manufacturer's specifications: ○ Check operation/continuity of the switch, transducer and wiring circuit with eg Ohm meter. ○ This is the only method to check the correct operation and integrity of the electrical system. • Fit appropriate oil pressure test gauge and run the engine (speed and temperature as manufacturer's instructions): ○ Check that the engine oil pressure meets manufacturer's specifications. ○ If the engine oil pressure is low, it indicates that there is a fault with an engine component (eg oil pump and engine lubrication system components). ○ This is the only method to check the true engine oil pressure. • Visual observation of engine oil for coolant/fuel contamination: ○ Confirm dilution and condition. ○ This is the only method to check the condition of the oil without professional analysis. Credit any other appropriate response.
Total marks	12
AO	AO2 – 4 marks AO3a –4 marks AO3b – 4 marks
Qual spec reference	5.1 Types of land-based equipment and machinery. 6.1 Operating principles of power units and associated integrated and stand-alone systems.

The T Level is a qualification approved and managed by the Institute for Apprenticeships and Technical Education.