Level 3
Technical Level Engineering

Materials' Technology and Science

Mark scheme

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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from aqa.org.uk

MARKING METHODS

In fairness to candidates, all examiners **must** use the same marking methods. The following advice may seem obvious, but all examiners **must** follow it as closely as possible.

1 If you have any doubt about how to allocate marks to an answer, consult your Team Leader.

2 Refer constantly to the mark scheme and standardising scripts throughout the marking period.

3 Use the full range of marks. Don't hesitate to give full marks when the answer merits them.

4 The key to good and fair marking is **consistency.**

INTRODUCTION

The information provided for each question is intended to be a guide to the kind of answers anticipated and is neither exhaustive nor prescriptive. **All appropriate responses should be given credit.**

Where literary or linguistic terms appear in the Mark Scheme, they do so generally for the sake of brevity. Knowledge of such terms, other than those given in the specification, is **not** required. However, when determining the level of response for a particular answer, examiners should take into account any instances where the candidate uses these terms effectively to aid the clarity and precision of the argument.

DESCRIPTIONS OF LEVELS OF RESPONSE

The following procedure must be adopted in marking by levels of response:

- read the answer as a whole
- work up through the descriptors to find the one which best fits
- where there is more than one mark available in a level, determine the mark from the mark range judging whether the answer is nearer to the level above or to the one below.

Since answers will rarely match a descriptor in all respects, examiners must allow good performance in some aspects to compensate for shortcomings in other respects. Consequently, the level is determined by the 'best fit' rather than requiring every element of the descriptor to be matched. Examiners should aim to use the full range of levels and marks, taking into account the standard that can reasonably be expected of candidates.

Q1 Malleability is the property of a material that allows it to be

[1 mark]

B) beaten into thin sheets.

1 mark for the correct answer.

Q2 Ductility can be best described as the ability to

[1 mark]

A) to be drawn into long thin wires.

1 mark for the correct answer.

Q3 Toughness is best described as

[1 mark]

D) the ability to withstand the propagation of cracks.

1 mark for the correct answer.

Q4 Hardness is a material's ability to resist

[1 mark]

C) scratches and abrasions.

1 mark the correct answer.

Q5 A material with a low thermal expansion coefficient will

[1 mark]

C) expand least at high temperature.

1 mark the correct answer.

Q6 A material that is low density will give rise to?

[1 mark]

B) low unit weight.

1 mark the correct answer.

Q7 High tensile strength allows a material to resist being

[1 mark]

D) pulled apart.

1 mark the correct answer.

Q8 Electrical conductivity relies on which material property

[1 mark]

B) resistivity.

1 mark the correct answer.

Q9 Which **one** of the materials listed below has the best corrosion resistance in a sea-water environment?

[1 mark]

A) stainless steel.

1 mark the correct answer.

Q10 Compressive strength is measured in units of

[1 mark]

D) N/m^2.

1 mark the correct answer.

Total marks for questions 1 to 10 inclusive is 10 marks.

Q11.1 Complete **Table 1** below for each material. Carbon Fibre Reinforced Plastic (CFRP) has been completed for you as an example..

[6 marks]

Table 1

Material	Class	Typical use
Carbon Fibre Reinforced plastic (CFRP)	Composite	Bicycle frame, fishing rod, car body panel etc.
Stainless Steel	Ferrous metal (allow metal). Not ferrous on its own. Not alloy on its own. Allow ferrous alloy.	Pipes and fittings, cooking utensils, food-processing equipment, sour gas applications, medical equipment, clean-room equipment, use in marine environments. Or any suitable application.
Rubber	Elastomers. Allow polymer.	Car / bike / lorry tyres, shock absorbers for buildings and docks, gaskets and seals. Or any suitable application.
Tungsten Carbide	Engineering Ceramic (allow ceramic).	Cutting tools and tips, balls for roller pens. Or any suitable application. Allow kitchen knives. No jewellery.

1 mark for each correct answer to a total of 6 marks.

Q11.2 The fuselage (**Figure 1**) of a commercial airliner is traditionally manufactured from which material?

[2 marks]

Aluminium alloy.
Don't allow titanium.

1 mark for aluminium and **2 mark** for aluminium alloy.
1 mark for composites and **2 marks** for carbon fibre.

Q11.3 Give **two** reasons why this material is used.

[2 marks]

Aluminium alloys have low density.
Aluminium alloys are easily worked.
Aluminium alloys are readily available.
Aluminium alloys have varied forms of supply.
Allow good good strength to weight ratio.
Allow corrosion resistance for aluminium alloy.

1 mark each for any of the above or other suitable reason.
10 marks in total for question 11.

Q12.1 Describe how high carbon steel can be hardened enough to make a metal cutting tool.

[4 marks]

- The material is heated up to cherry red.
- Temperature in the range: 800^0C to 850^0C.
- Then rapidly quenched.
- In either cool oil or cool salty water

1 mark for each correct point made (max 4 marks).

Q12.2 Brittleness is one unwanted property that is a direct result of the hardening process.
Name a heat treatment process that will reduce its affects.

[1 mark]

Tempering. But do allow Annealing and Normalising.

1 mark for the answer above.

Q12.3 Name the class of material that polyethylene belongs to.

[1 mark]

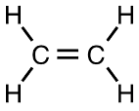
Thermoplastic polymer. (accept thermoplastic and polymer)

1 mark for the above answer.

Q12.4 Provide a sketch of the monomer for polyethylene in the space provided.

[2 marks]

1 mark for 2C and 4H atoms.



1 mark for the double carbon bond.

Q12.5 Describe the process of polymerisation.

[2 marks]

1 mark many small molecules join together.
1 mark to make very long molecules or chains called polymers.
1 Mark for crosslinks.

2 marks for this or other suitable response.
Total for question 12 is 10 marks.

Q13.1 Determine the current flowing in the circuit showing the correct units in your answer.

[5 marks]

Using: $P = VI$ and $I = \frac{P}{V}$
Therefore, we have: $I = \frac{60}{24} = \frac{5}{2} = 2.5\ \text{Amperes}$. Allow Amps.

1 mark for correct formula.
1 mark for correct transposition.
1 mark for correct values.
1 mark for correct answer.
1 mark for correct units.

5 marks in total for Question 13.1.

Q13.2 Calculate the resistance of the lamp showing the correct units in your answer.

[5 marks]

Using: $V = IR$ and $R = \frac{V}{I}$
Thus, we have: $R = \frac{24}{2.5} = \frac{48}{5} = 9.6\Omega\ (\text{Ohms})$.

1 mark for correct formula.
1 mark for correct transposition.
1 mark for correct values.
1 mark for correct answer.
1 mark for correct unit – allow a mark for either the symbol or words.

5 marks in total for Question 13.2.

10 marks in total for Question 13.

Allow follow-through if necessary from part 13.1 above.

Q14.1 Describe what is meant by laminar flow in a fluid control system.

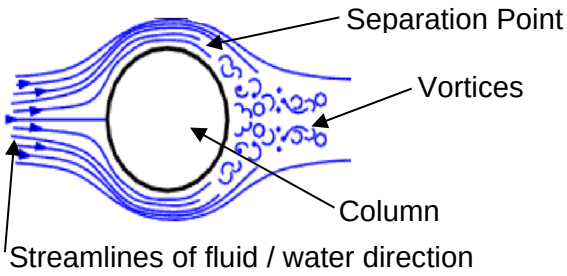
[3 marks]

In fluid dynamics, **laminar flow** (or streamline flow) occurs when a fluid flows in parallel layers, with no disruption between the layers. At low velocities, the fluid tends to flow without lateral mixing, and adjacent layers slide past one another like playing cards. There are no cross-currents perpendicular to the direction of flow, nor eddies or swirls of fluids.

1 mark for parallel layers.
1 mark for low velocities.
1 mark for no swirls, vortices or eddies
Allow any another similar responses.
3 marks in total for Question 14.1.

Q14.2 Describe, with the aid of a labelled diagram, water flowing past a circular column in a river.

[4 marks]



Fluid will flow around the column, separate and develop a vortex wake (vortex shedding) behind / downstream of the column.

1 mark for mention / drawing of vortices.
1 mark for a good diagram – (must show water direction, column and the effect of the column).
1 mark for mentioning / drawing separation points.
1 mark for a textual or similar explanation.

4 marks in total for Question 14.2.

Q14.3 Describe what is meant by heat conduction in metals.

[3 marks]

Metals are good conductors of heat, but non-metals and gases are usually poor conductors of heat. Heat energy is conducted from the hot end of an object to the cold end.

The electrons in piece of metal can leave their atoms and move about in the metal as free electrons. The parts of the metal atoms left behind are now charged metal ions. The ions are packed closely together and they vibrate continually. The hotter the metal, the more kinetic energy these vibrations have. This kinetic energy is transferred from hot parts of the metal to cooler parts by the free electrons. These move through the structure of the metal, colliding with ions as they go.

1 mark for electrons moving around in metals.

1 mark for kinetic energy and vibration.

1 mark for hotter parts transferring to cooler parts.

1 mark for thermal energy.

3 marks in total for Question 14.3.

10 marks in total for Question 14.

Q15 The gas in the cylinder of an internal combustion engine at the start of the compression stroke has volume of $0.015m^3$, temperature of 20^0C and pressure of 1.8 bar g. The piston compresses the gas to $0.005m^3$ and pressure of 8 bar g.

Q 15.1 By use of the gas laws, determine the final temperature of the gas giving your answer in **absolute values.**

[8 marks]

First do the conversions:
$P_1 = 1.8 \times 101 \times 10^3 = 181.8kPa.$
$P_2 = 8 \times 101 \times 10^3 = 808kPa.$
$T_1 = 20^0C + 273 = 293K.$

Using the combined Gas Laws we have:

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ Transposing to find T_2 we have:

$T_2 = \frac{P_2V_2T_1}{P_1V_1}$ and inserting the values we have:

Now insert the values into the equation:

$T_2 = \frac{808\times10^3\times0.005\times293}{181.8\times10^3\times0.015} = 434K.$

1 mark for use of the correct equation.
1 mark for each conversion – 3 marks maximum.
2 marks for the transposition.
1 mark for the correct result.
1 mark for use of Kelvins in the answer.

8 marks in total for Question 15.1.

Q15.2 Explain why the temperature changes during compression.

[2 marks]

The temperature changes due to the conservation of energy; mechanical work on the fluid is converted into heat via the increased kinetic energy contained within the molecules of the fluid as it undergoes compression.

1 mark for mechanical work.
1 mark for increased kinetic energy.

2 marks in total for Question 15.2.

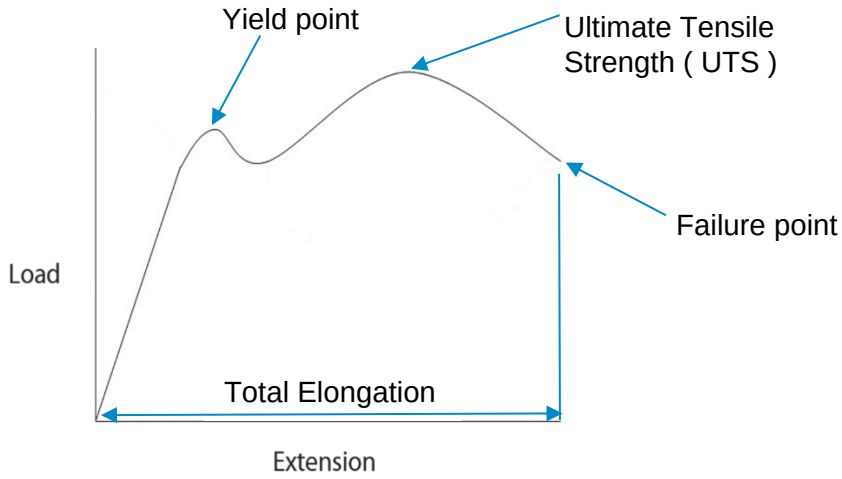
10 marks in total for Question 15.

Q16 A method widely used throughout the engineering industry to test metallic materials is the tensile test.

Q16.1 Draw the load / extension curve / graph for typical low carbon steel. Label the following points on your curve / graph:

- yield point;
- ultimate tensile strength;
- total elongation; and
- the failure point.

[5 marks]



1 mark for a suitably reproduced curve similar to the one above.
1 mark for each point shown up to a total of 4 marks.

5 marks in total for Question 16.1

Q16.2 A $15\ mm$ diameter carbon steel tie-bar is subjected to a load of $20kN$ whilst being used on an electricity pylon. Determine the direct stress produced in this component.

[5 marks]

Calculate the cross-sectional area of the component:

$A = \frac{\pi D^2}{4} = \frac{\pi \times (15 \times 10^{-3})^2}{4} = 177 \times 10^{-6} m^2$ and

$\sigma = \frac{F}{A} = \frac{20000\ N}{177 \times 10^{-6} m^2} = 113 MPa \equiv 113 MN m^{-2}.$

1 mark for correct formula for the area.
1 mark for correct area.
1 mark for correct stress equation.
1 mark for correct values.
1 mark for correct units – accept either unitary measure.
5 marks in total for Question 16.2.

10 marks in total for Question 16.

Q17 Corrosion costs engineering industries a large amount of money each year.

Q17.1 Explain why metals corrode.

[4 marks]

Corrosion is degradation of materials' properties due to interactions with their environments, and corrosion of most metals (and many materials for that matter) is inevitable. While primarily associated with metallic materials, all material types are susceptible to degradation.

The fundamental cause or driving force for all corrosion is the lowering of a system's Gibbs energy. The production of almost all metals (and engineering components made of metals) involves adding energy to the system. As a result of this thermodynamic struggle, the metal has a strong driving force to return to its native, low energy oxide state. This return to the native oxide state is what we call corrosion and even though it is inevitable, substantial barriers (corrosion control methods) can be used to slow its progress toward the equilibrium state.

1 mark for degradation.
1 mark for chemical reaction with its environment.
1 mark for added energy into the system during manufacture.
1 mark for strong driving force to return back to their native oxides.
1 mark brittle oxide / rust.

Allow any other suitable responses

4 marks in total for Question 17.1.

Q17.2 Describe how aluminium and its alloys protect themselves from atmospheric corrosion when being used.

[2 marks]

Untreated aluminium has very good corrosion resistance in an atmospheric environment primarily because aluminium spontaneously forms a thin but effective oxide layer that prevents further oxidation. Aluminium oxide is impermeable and, unlike the oxide layers on many other metals, it adheres strongly to the parent metal. If damaged mechanically, aluminium's oxide layer repairs itself immediately.

1 mark for oxide layer.
1 mark for self-repairing.

Allow any other suitable similar responses

2 marks for Question 17.2.

Q17.3 Identify **four** corrosion protection methods used to protect engineering metals whilst in service.

[4 marks]

- Alloying with other metals; for example, Chromium, Nickle etc.
- Painting the surface.
- Galvanising.
- Plating with other metals; for example, Chromium, electro-less-Nickle etc.
- Epoxy powder coating.
- Sacrificial anodes.
- Polymeric coatings.
- Cathodic protection.
- Impressed current protection.
- Allow 1 mark for oxide layer (as in aluminium alloy).

Any suitable other protection system will be acceptable.

1 mark for any of the above or suitable other up to a total of 4 marks.

4 marks in total for Question 17.3.

10 marks in total for Question 17.

80 marks in total for the whole paper.

Assessment outcomes coverage

Assessment Outcomes	Marks and % of marks available in section A	Marks and % of marks available in section B	Total Marks
AO1:	10 marks 20%	10 marks 33.3%	20
AO2:	10 Marks 20%	00 marks 00%	10
AO3:	10 Marks 20%	10 marks 33.3%	20
AO4:	10 Marks 20%	00 marks 00%	10
AO5:	10 Marks 20%	10 marks 33.3%	20
Total Marks	50	30	80

Question	Assessment Outcome 1	Assessment Outcome 2	Assessment Outcome 3	Assessment Outcome 4	Assessment Outcome 5
1	1				
2	1				
3	1				
4	1				
5	1				
6	1				
7	1				
8	1				
9	1				
10	1				
11		10			
12			10		
13				10	
14					10
15					10
16	10				
17			10		
Totals	**20**	**10**	**20**	**10**	**20**