Level 3 Technical Level
DESIGN ENGINEERING
MECHATRONIC ENGINEERING
F/506/5952

Unit 1 Materials Technology and Science

Mark scheme

January 2019

Version 1.0 Final

I91Af5065952/MS

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

Level of response marking instructions

Level of response mark schemes are broken down into levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Step 1 Determine a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level, ie if the response is predominantly level 3 with a small amount of level 4 material it would be placed in level 3 but be awarded a mark near the top of the level because of the level 4 content.

Step 2 Determine a mark

Once you have assigned a level you need to decide on the mark. The descriptors on how to allocate marks can help with this. The exemplar materials used during standardisation will help. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme.

An answer which contains nothing of relevance to the question must be awarded no marks.

SECTION A

The following list indicates the correct answers used in marking candidates' responses to the multiple-choice questions.

KEY LIST

1	**C**
2	**D**
3	**A**
4	**B**
5	**C**
6	**D**
7	**A**
8	**C**
9	**B**
10	**C**

1 1 . 1 Complete **Table 1** by entering the material class and typical use.
The top row has been completed for you as an example.

[6 marks]

Table 1

Material	**Class**	**Typical Use**
Brass	Non-ferrous metal	Ornaments, bullet cartridges, bells, plumbing application, door knobs, electrical applications etc.
High impact polystyrene (HIPS)	Thermoplastic polymer. Don't accept polymer on its own. Don't accept plastic. Accept thermoplastic.	Toilet seats, bathroom cabinets, TV and audio-visual equipment parts, bicycle trailers, children's toys. Any other valid use.
Cast iron	Ferrous metal. Don't accept metal on its own.	Cooking utensils, manhole covers, industrial plumbing equipment, cylinder liners, piping, stoves, cookware. Any other valid use.
Silicon carbide	Engineering ceramic. Accept ceramic.	Gas turbine components, seals and bearings, ball valve components, heat exchanger components, abrasives, refractories, ballistic glass. Any other valid use.

1 1 . 2 State **two** materials that Component **A** is commonly manufactured from.

[2 marks]

Accept:
- low carbon steel
- mild steel
- thermoplastic polymer
- aluminium
- stainless steel

Or any material given by name; for example, ABS, HDPE, HIPS etc.
Or any suitable material by name or class.

Don't accept:
- engineering ceramics
- titanium
- tungsten
- sliver
- reinforce concrete, etc

1 1 . 3 Give **two** reasons why these materials can be used.

[2 marks]

Accept any of the following:
- corrosion resistance
- forms of supply
- toughness
- ease of manufacture
- strong
- cost effective
- hardness

Or any other suitable response.

1 2 . 1 Explain briefly what is meant by an alkane structure.
Give an example of **one** in your answer.

[3 marks]

Explanation: An alkane is a hydrocarbon in which all carbon atoms are bonded by single atoms, this means they are **saturated**.

1 mark for hydrocarbon
1 mark for carbon atoms
1 mark for saturated
Up to 2 marks maximum.

1 mark for methane/ethane/propane/butane/pentane/hexane.

Or any other suitable response.

1 2 . 2 Explain what is meant by crosslinking in polymers and how it affects the property of the material.

[7 marks]

Crosslinking is where the polymer chains are chemically joined together in places, by covalent bonds. The polymer molecules cannot slide over each other so easily. This makes materials tougher and less flexible, and they cannot be easily stretched. Crosslinking also gives materials high melting points.

1 mark for chains
1 mark for chemically joined
1 mark for covalent bonds
1 mark for can't slide past each other easily
1 mark for tough
1 mark for can't be easily stretched
1 mark difficult to recycle (particularly with more bonds)
1 mark for high melting points
1 mark for less flexible.
1 mark for difficult to recycle.

Maximum of 7 marks for any of these or other suitable responses.

1 3 . 1 Explain the function of an electronic transistor.

[5 marks]

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal.

1 mark for semiconductor
1 mark for switch electronic signals
1 mark for 3 terminals
1 mark for connected to an external circuit
1 mark for voltage/current applied to one pair of the transistors terminals
1 mark for controlling current through another pair of terminals
1 mark for amplify a signal
1 mark for can flow in both directions

Maximum of 5 marks for any of these or other suitable responses.

1 3 . 2 Give the correct terms for the properties of the waveform indicated by points **A**, **B** and **C** on **Figure 2**.

[3 marks]

Point A: Periodic Time.
Point B: Amplitude.
Point C: Peak-peak Voltage.

1 mark for each correct answer. **Maximum 3 marks.**

1 3 . 3 Give **two** engineering examples of where sine waveforms can be found.

[2 marks]

- Voltage/current/power in AC electrical circuits.
- Soundwaves/light waves.
- Crankshafts/pistons rotation/sliding.
- Communications systems between electronic components.
- Vibrations on electrical generators/transformers.
- Analogue signal.

Or any other suitable response to a **maximum of 2 marks**.

1 4 . 1 Identify the **three** phenomena listed on **Figure 3**.

[3 marks]

Phenomenon A: Separation point
Phenomenon B: Turbulent flow
Phenomenon C: Laminar flow.

1 4 . 2 Explain what is meant by the stagnation point in a two-dimensional fluid flow system.

[2 marks]

In fluid dynamics, a stagnation point is a point in a flow field where the local velocity of the fluid is zero. Stagnation points exist at the surface of objects in the flow field, where the fluid is brought to rest by the object.

1 mark for velocity of the fluid is zero
1 mark for brought to rest by the object

Or similar responses.

1 4 . 3 Describe how to calculate the efficiency of a simple machine.

[3 marks]

Efficiency for a **simple machine** is (useful work out)/(total work in). This expression is multiplied by 100 to give percentage **efficiency.**

2 marks for output/input
1 mark for multiply by 100 to get a percentage

Maximum 3 marks

1 4 . 4 Briefly explain what is meant by friction in a mechanical power transmission system.

[2 marks]

Friction is the force resisting the relative motion of solid surfaces and material elements sliding against each other.

1 mark for force
1 mark for resisting motion
1 mark for material elements
1 mark for sliding against each other
1 mark for generate heat

Any of the above or other suitable answers for a **maximum of 2 marks**

SECTION B

1 5 . 1 Calculate the volume of the cylinder.

Give your answer to 3 decimal places using the correct engineering units.

[4 marks]

Volume of the cylinder is:

$$V = \frac{\pi D^2}{4} h = \frac{\pi \times 1.2^2}{4} \times 1.75 = 1.9792\ldots \text{ m}^3$$

(allow the use of πr^2 also)

The volume of the cylinder: $V = 1.979$ m^3 to 3 d.p.

1 mark for correct formula
1 mark for the correct calculation/value
1 mark for the correct units
1 mark for 3 d.p.

1 5 . 2 Use the characteristic gas equation and the volume calculated in question **15.1** to calculate the mass of air.

$pV = mRT$ where:

$p = 1.25$ MPa
$R = 287.05$ J kg^{-1} K^{-1}
$T = 75$°C
m = mass

[6 marks]

$$m = \frac{pV}{RT} = \frac{1.25 \times 10^6 \times 1.9792\ldots}{287.05 \times 348} = 24.7664\ldots \text{ kg}$$

Therefore, the mass of the gas in the cylinder is: 24.8 kg 3 sig. fig.

2 marks for correct transposition
1 mark for correct value in Kelvin
1 mark for use of correct values of MPa
1 mark for correct answer
1 mark for 3 sig. fig

Omit 1 mark if °C have been used in the calculation

1 6 . 1 Calculate the tensile stress in the tie-bar to 3 significant figures.

[5 marks]

$$\sigma = \frac{F}{A}$$

Where:

$$A = \frac{\pi D^2}{4} \text{ or } \pi r^2 = \frac{\pi \times (20 \times 10^{-3})^2}{4} = 314.1592\ldots \times 10^{-6} \text{m}^2$$

or equivalent.

Therefore, stress:

$$\sigma = \frac{F}{A} = \frac{50000}{314.1592\ldots \times 10^{-6}} = 159.1549\ldots \times 10^6 \text{ Nm}^{-2} = 159 \text{ MPa}$$

3 sig. fig.

1 mark for correct formula for area – allow either
1 mark for correct calculation
1 mark for correct formula for stress
1 mark for correct calculation
1 mark for 3 sig. fig

1 6 . 2 Calculate the extension in the tie-bar in millimetres to 1 decimal place.

[5 marks]

$$E = \frac{\sigma}{\epsilon} \therefore \epsilon = \frac{\sigma}{E} = \frac{159.1549\ldots \times 10^6}{200 \times 10^9} = 795.7747\ldots \times 10^{-6}$$

$$\epsilon = \frac{\Delta l}{l_o} \therefore \Delta l = \epsilon l_o = 795.7747\ldots \times 10^{-6} \times 2000 = 1.5915\ldots \text{ mm}$$

or 1.6 mm 1 d. p.

1 mark for correct Young's Modulus formula
1 mark correct calculation
1 mark for correct strain formula transposition
1 mark for correct answer
1 mark for correct decimal places

1 7 . 1 Explain the process of corrosion in metals.

[3 marks]

Corrosion is a naturally occurring electrochemical process. The presence of a tiny amount of electrolyte on an unprotected metal surface can cause electrons to flow from a higher energy area (anode) to a lower energy area (cathode) initiating and sustaining corrosion. Microscopic droplets of water that are present in the air at 70–85% relative humidity most commonly serve as the electrolyte.

1 mark for electrochemical process
1 mark for higher energy (anode)
1 mark for lower energy (cathode)
1 mark for drops of electrolyte / water
1 mark for colour change
1 mark for oxidation
1 mark for metal flaking away, falling of etc.

Or other similar/suitable/relevant responses. **3 marks maximum.**

1 7 . 2 Explain how different metals, used together, can inhibit corrosion.

[2 marks]

Stainless steels are notable for their corrosion resistance, which increases with increasing chromium content. Molybdenum additions increase corrosion resistance in reducing acids and against pitting attack in chloride solutions. Thus, there are numerous grades of stainless steel with varying chromium and molybdenum contents to suit the environment the alloy must endure. Thus stainless steels are used where both the strength of steel and corrosion resistance are required.

1 mark for an explanation
1 mark for use/mention of another metal

Galvanising is a method of rust prevention. The iron or steel object is coated in a thin layer of zinc. This stops oxygen and water reaching the metal underneath - but the zinc also acts as a sacrificial metal. Zinc is more reactive than iron, so it oxidises in preference to the iron object.

1 mark for explanation
1 mark for use/mention of another metal

Electroless nickel plating actually uses a solution that is a nickel phosphorous alloy and the plating solution composition can be tailored to suit a particular application. High phosphorous electroless nickel offers a pore free barrier coating that protects the underlying substrate form attack and offers outstanding chemical resistance and corrosion protection.

1 mark for explanation
1 mark for use/mention of another metal

Any of the above answers or other suitable answers will suffice. These are only possible examples.

1 7 . 3 Give **five** benefits of corrosion protection.

[5 marks]

1 mark for long term integrity of engineering assets
1 mark for avoiding costly engineering failures
1 mark for lower pollution and chemical/gas releases
1 mark for reduction in energy costs to recycle engineering materials
1 mark for helps to keep people employed in the corrosion protection industry
1 mark for help prevent disasters and loss of life/injury and the cost of claims
1 mark for protects resources/elements' supply for future generations
1 mark for helps make engineered devices/artefacts/machines more efficient
1 mark for helps to predict the longevity of engineered devices and components
1 mark for helps increase the sustainability of engineering materials
1 mark for aesthetics.

Any of these or other suitable responses. **5 marks maximum.**

Assessment outcomes coverage

Assessment Outcomes	Marks and % of marks available in section A	Marks and % of marks available in section B	Total Marks
AO1:	04 marks 08%	10 marks 33.3%	14
AO2:	10 Marks 20%	05 marks 16.7%	15
AO3:	12 Marks 24%	05 marks 16.7%	17
AO4:	12 Marks 24%	00 marks 00%	12
AO5:	12 Marks 24%	10 marks 40%	22
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	2	8			
12			10		
13				10	
14					10
15					10
16	10				
17		5	5		
Totals	**14**	**15**	**17**	**12**	**22**