AQA

Level 3 Technical Level
Design Engineering
Mechatronic Engineering
F/506/5952

Unit 1 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.

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Question	Marking Guidance	Marks
01	B	1
02	D	1
03	C	1
04	A	1
05	A	1
06	D	1
07	C	1
08	B	1
09	A	1
10	B	1

Question	Marking Guidance	Marks

11.1

Complete Table 1 by entering the material class and a suitable application. The top row has been completed for you as an example.

1 mark for each correct answer up to a maximum of **6 marks**. Max **3 marks** for class and max **3 marks** for typical use.

Material	**Class**	**Typical use (any other suitable responses)**
Melamine formaldehyde	Thermosetting polymer	Household items – such as glasses, cups, bowls and plates. Toilet seats, light switches and pan handles.
Thermochromic materials	Smart Materials	Sunglasses, data storage, solar energy storage. Temperature indicators.
Polyvinyl chloride (PVC)	Thermoplastic polymers Don't allow polymers.	Construction profiles, medical devices, roofing membranes, credit cards, children's toys and casing for wires. Allow glue and bottles.
Titanium	Non-ferrous metals. Don't allow metal on its own.	Used as a pigment in house paint, artists' paint, plastics, enamels and paper, sunscreens, power plant condensers, protection of hulls of ships, submarines and other structures exposed to seawater. Surgical applications such as in joint replacements (especially hip joints) and tooth implants. Exhaust systems.

Or other suitable responses.

Marks: **6**

11.2

The frame of the mountain bike is commonly manufactured from which material?

Aluminium alloy or Carbon Fibre Reinforced Plastic (CFRP) or low carbon steel. Don't allow high carbon steel or stainless steel.

1 mark for aluminium. **1 mark** for carbon fibre. **1 mark** carbon.
1 mark for alloy. **1 mark** for reinforced plastic. **1 mark** steel.

up to a maximum of **2 marks**

Marks: **2**

Question	Marking Guidance	Marks
11.3	**Give two reasons why this material is used.** Both classes have good strength. Both classes of material are low density. Both classes of material are stiff. Both classes of material can be used in manufacturing quite easily. Don't allow malleable. **1 mark** each for any of the above or other suitable reason up to a maximum of **2 marks**.	**2**
12.1	**Name the three labelled regions indicated on Figure 2.** A Point: The eutectic point. Allow melting point as a BoD. B Phase: The liquid phase. C Phase: The solid phase. **1 mark** for each correct point made.	**3**
12.2	**Describe the stages of the process for case hardening of steel.** Carbon is added to the outer surface of the steel, to a depth of approximately 0.03mm. The steel is heated to red heat. It may only be necessary to harden one part of the steel and so heat can be concentrated in this area. The steel is removed from the brazing hearth with blacksmiths' tongs and plunged into case hardening compound and allowed to cool a little. The case hardening compound is high in carbon. The steel is heated again to a red colour, removed from the brazing hearth and plunged into cold, clean water. The steel rod should now have a hardened outer surface and a flexible, soft interior. The process can be repeated to increase the depth of the hardened surface. **1 mark** for carbon is added to the outer surface of the steel. **1 mark** for 0.03 mm (or similar depth, don't be too harsh). **1 mark** Steel is heated to red heat. **1 mark** for case hardening compound. **1 mark** for heating steel to red heat. **1 mark** for cold water. **1 mark** for repeating process to get extra depth. or other suitable responses up to a maximum of **7 marks**.	**7**

Question	Marking Guidance	Marks
13.1	**Describe how a diode works in an electronic circuit.** A diode is a discrete component that allows current to flow in one direction only. It is a polarised component with two leads, called the cathode and the anode. The cathode is normally marked with a silver or coloured band or the symbol '-'. If the anode is connected to a higher voltage than the cathode, current will flow from anode to cathode. This is called forward bias. If the diode is put in the circuit back to front, so that the voltage at the cathode is higher than the voltage at the anode, the diode will not conduct electricity. This is called reverse bias. **1 mark** for allows current to flow in one direction only. **1 mark** for anode. **1 mark** for cathode. **1 mark** for forward bias. **1 mark** for reverse bias. or other suitable responses up to a maximum of **5 marks**.	5
13.2	**Describe how electromagnetic induction is used in a voltage transformer.** When a DC current pass through a long straight conductor a magnetising force, H (field strength) and a static magnetic field, B (flux density) is developed around the wire. If the wire is then wound into a coil, the magnetic field is greatly intensified producing a static magnetic field around itself forming the shape of a bar magnet giving a distinct North and South pole. The magnetic flux developed around the coil being proportional to the amount of current flowing in the coils windings. If additional layers of wire are wound upon the same coil with the same current flowing through them, the static magnetic field strength would be increased. **1 mark** for magnetising force. **1 mark** for magnetic field. **1 mark** for coil of wire intensifying the magnetic field. **1 mark** for magnetic flux developed around the coil being proportional to the amount of current flowing in the coils windings. **1 mark** for additional layers of wire increasing magnetic field strength. or other suitable responses up to a maximum of **5 marks**.	5

Question	Marking Guidance	Marks
14.1	**Describe what is meant by latent heat of fusion.** **1 mark** for a limited response, such as the energy required to melt a solid **2 marks** for a detailed response, such as the heat absorbed by a unit mass of a given solid at its melting point that completely converts the solid to a liquid at the same temperature	**2**
14.2	**Describe in detail the operation of a heat pump using a suitable example.** Award up to **6 marks** as follows: Heat pumps transfer heat from an area of relatively high temperature to an area or relatively low temperature, or vice versa (**1 mark**). They do this by circulating a substance called a refrigerant (**1 mark**) through a cycle of evaporation and condensation (**1 mark**). A compressor pumps the refrigerant between two heat exchanger coils (**1 mark**). In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings (**1 mark**). The refrigerant is then compressed en route to the other coil, where it condenses at high pressure (**1 mark**). At this point, it releases the heat it absorbed earlier in the cycle (**1 mark**). **An example of a heat pump**: Air conditioning, fridge, freezer, HVAC systems. Don't allow radiator as an example. **1 mark** for any of these or any other suitable response.	**6**
14.3	**What is the SI unit of thermal energy?** **1 mark** for the Joule or Nm or J.	**1**
14.4	**What is the SI unit of thermal power?** **1 mark** for the Watt or Nm / s allow J / s.	**1**

Question	Marking Guidance	Marks
15.1	**Calculate the length of the beam, L_t, at $70\ ^0C$ and $-30\ ^0C$ if $\alpha = 16.0 \times 10^{-6} m\, m^{-1} K^{-1}$** $L_t = L_0(1 + \alpha\Delta T)$ inserting values, we have: $L_t = 6\left(1 + 16.0 \times 10^{-6}(70^0 - 20^0)\right)$ $L_t = 6.005\ m\ to\ 3\ d.p.$ At 70^0C. $L_t = 6\left(1 + 16.0 \times 10^{-6}(-30^0 - 20^0)\right)$ $L_t = 5.995\ m\ to\ 3\ d.p.$ At -30^0C. **1 mark** for use of the correct values. **1 mark** for the correct way to calculate ΔT. **1 mark** for the correct answer. **1 mark** for the use of 3 d. p. At 70^0C. **1 mark** for the correct way to calculate ΔT. **1 mark** for the correct answer. **1 mark** for the use of 3 d. p. At -30^0C.	**7**
15.2	**State two mechanical properties and one physical property required for a steel beam.** • Tensile strength. • Compressive strength. • Elasticity. • Toughness. • Hardness. • Corrosion resistance. • Low thermal expansion. • Torsional strength / stiffness. • High melting point. • Stiffness. **1 mark** for any of the above or other suitable response up to a maximum of **3 marks**. Don't be too harsh, especially if a candidate names three mechanical properties.	**3**

Question	Marking Guidance	Marks
16	If **Gear A** is rotating at 30 RPM in a clockwise direction, determine the speed and direction of **Gear D** using the information from **Table 2**. $R = \frac{\omega_{in}}{\omega_{out}} = \frac{N_{out}}{N_{in}}$ A rotates clockwise at 30RPM. $\frac{\omega_{in}}{\omega_{out}} = \frac{N_{out}}{N_{in}} \therefore \frac{\omega_A}{\omega_B} = \frac{N_B}{N_A}$ and $\omega_B = \frac{\omega_A N_A}{N_B}$ Thus: $\omega_B = \frac{30\times120}{40} = 90RPM$ Anticlockwise. Because gear C is connected to gear B they will be rotating at the same speed in the same direction. $\frac{\omega_C}{\omega_D} = \frac{N_D}{N_C}$ and $\omega_D = \frac{\omega_C N_C}{N_D}$ Thus: $\omega_D = \frac{90\times80}{20} = 360\ RPM$ Clockwise. **1 mark** for the correct formula. **1 mark** for the correct symbols. **1 mark** for the correct transposition. **1 mark** for the correct values. **1 mark** for the correct answer. **1 mark** for correctly stating $\omega_B = \omega_C$. **1 mark** for the correct transposition. **1 mark** for the values. **1 mark** for the correct answer.	**10**

Question	Marking Guidance	Marks
17.1	**Describe the effects of cold working an aluminium alloy.** Cold working produces additional dislocations within the metal structure. When two or more dislocations meet, the movement of one tends to interfere with the movement of the other. The more dislocations there are, the more they will hinder each other's movement. As the working continues, however, the movement of the dislocations becomes more difficult. This increases the strength of the metal and also makes it stiffer. **1 mark** for dislocations. **1 mark** for movement of one tends to interfere with the other. **1 mark** for movement of the dislocations becomes more difficult. **1 mark** for increases strength (accept stiffness or hardness) of the materials. **1 mark** for increase in internal stress. Maximum of 4 marks.	4

`Question	Marking Guidance	Marks
17.2	**Explain in detail how normalising changes the properties of steel.** Award up to **6 marks** as follows: Normalising involves heating the steel to just above its upper critical point (**1 mark**), soaking it for a short period at that temperature (**1 mark**) and then allowing it to cool in air (**1 mark**). This creates a fine grain structure (**1 mark**) which results in a tougher (**1 mark**), more ductile (**1 mark**) material. It also eliminates columnar grains and dendritic segregation (**1 mark**) that sometimes occurs during casting (**1 mark**). It improves machinability (**1 mark**) and improved dimensional stability if the material is subjected to further heat treatment processes (**1 mark**). Any other relevant point.	6

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**