Engineering marking guide and response

External assessment 2025

Combination response (77 marks)

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

1. recognise and describe machine and mechanism problems, and mechanics, materials science and control technologies concepts and principles, in relation to machines and mechanisms
2. symbolise and explain ideas and solutions in relation to machines and mechanisms
3. analyse machine and mechanism problems, and information in relation to machines and mechanisms
5. synthesise information and ideas to predict possible machine and mechanism solutions.

Note: Objectives 4, 6, 7 and 8 are not assessed in this instrument.

Purpose

This document consists of a marking guide.

The marking guide:

- provides a tool for calibrating external assessment markers to ensure reliability of results
- indicates the correlation, for each question, between mark allocation and qualities at each level of the mark range
- informs schools and students about how marks are matched to qualities in student responses.

Mark allocation

Where a response does not meet any of the descriptors for a question or a criterion, a mark of '0' will be recorded.

Allow FT mark/s — refers to 'follow through', where an error in the prior section of working is used later in the response, a mark (or marks) for the rest of the response can still be awarded so long as it still demonstrates the correct conceptual understanding or skill in the rest of the response.

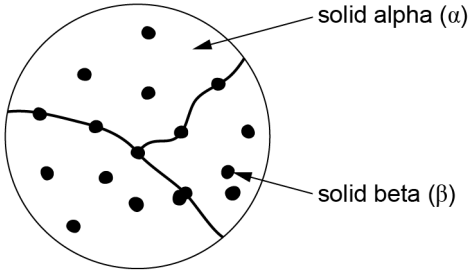
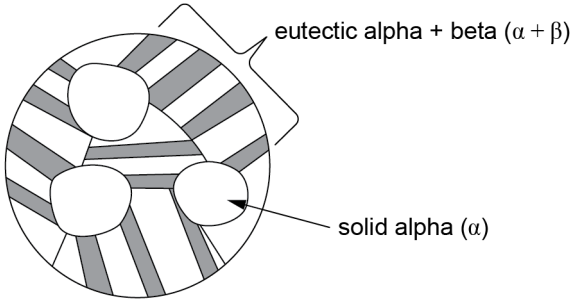
Rounding for results to intermediate steps in calculation questions is considered correct when provided within a range of two to a maximum of nine decimal places as determined using a scientific calculator. Final answers must be provided to the nearest whole unit or as otherwise stated in the question.

Marking guide

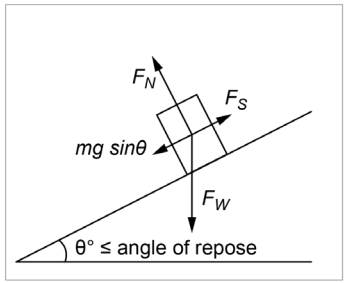
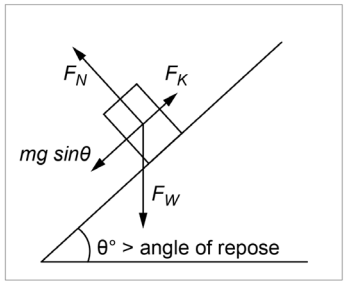
Multiple choice

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

Short response

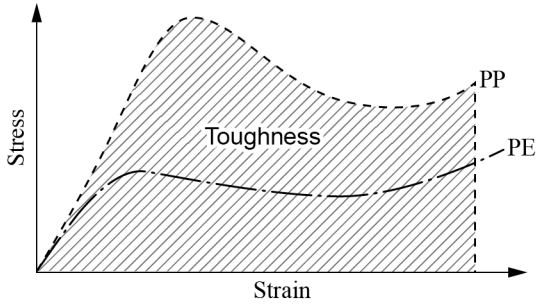
Q	Sample response	The response:
11a)		• correctly labels the alpha phase **[1 mark]** • correctly labels the beta phase **[1 mark]**
11b)		• correctly labels the eutectic (alpha and beta) phase **[1 mark]** • correctly labels the alpha phase **[1 mark]**

Q	Sample response	The response:
12	Mild carbon steel is softer and more ductile than high carbon steel as it contains a high amount of ferrite. Conversely, high carbon steel is harder and more wear resistant than mild carbon steel because it contains a higher amount of cementite. Industrial knives are required to be very sharp and to maintain their sharpness; therefore, high carbon steel is the most suitable material for this application.	• identifies a suitable property of mild carbon steel **[1 mark]** • makes a comparison regarding the property **[1 mark]** • identifies a suitable property of high carbon steel **[1 mark]** • makes a comparison regarding the property **[1 mark]** • identifies that high carbon steel is the most appropriate material for industrial knives **[1 mark]**

Q	Sample response	The response:
13	Static friction  Kinetic friction  The coefficient of static friction μ_s is the amount of friction between two surfaces that are not moving in relation to each other. When an object on an inclined plane is not moving, the angle of the incline *θ* must be less than or equal to the angle of repose, the angle at which an object on an inclined plane is just about to slide. The coefficient of kinetic friction μ_k is the amount of friction between two surfaces when there is movement between them. For an object to start to move or slide down the inclined plane, the angle of the incline *θ* must be greater than the angle of repose.	• provides a correctly labelled force diagram to support the description of – static friction **[1 mark]** – kinetic friction **[1 mark]** • correctly describes – static friction **[1 mark]** ▪ in terms of the angle of repose **[1 mark]** – kinetic friction **[1 mark]** ▪ in terms of the angle of repose **[1 mark]**

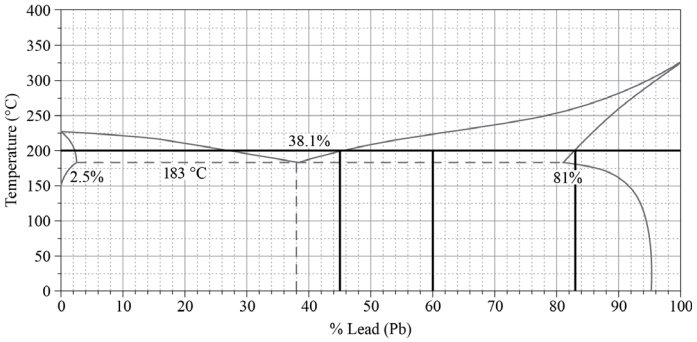
Q	Sample response	The response:
14a)	Polymer B is the most suitable because it has high yield stress, making it resistant to plastic deformation and able to withstand considerable stress without permanently changing shape. It also has a high Young's modulus, indicating a stiff material, able to resist elastic deformation. As such, it can withstand high loads and return to its original shape when the load is removed, but not so stiff that it is brittle.	• identifies polymer B as the most suitable polymer **[1 mark]** • justifies the selection using – one feature from the stress–strain diagram **[1 mark]** – a second feature from the stress–strain diagram **[1 mark]**
14b)	Polymer C is the most suitable because it has high toughness, which is needed to absorb a lot of energy, while also having high ultimate tensile strength, making it able to withstand a high amount of stress while deforming plastically before the material fails or breaks.	• identifies polymer C as the most suitable polymer **[1 mark]** • justifies the selection using – one feature from the stress–strain diagram **[1 mark]** – a second feature from the stress–strain diagram **[1 mark]**

Q	Sample response	The response:
15	To prevent unlawful access to property, engineers have used their expertise in mechanics to develop multipoint locks that provide multiple locking points around doors or window frames by moving multiple metal components from one central point in the lock. Their expertise in materials science ensures that the locking mechanisms are made of strong and durable materials resistant to damage or tampering. To allow authorised persons to operate the locking mechanisms and prevent unauthorised access, engineers have used their expertise in control technology, e.g. logic gate circuits that have input devices such as swipe cards, keypads or biometrics. Having more secure and durable locks on windows and doors will reduce the potential costs for small business owners that result from theft or vandalism caused by intruders. Additionally, the use of controlled entry of authorised persons could provide the business with a record of who has been on the premises and when.	• identifies a valid machine/mechanism solution **[1 mark]** • explains how the engineers have used their expertise in materials science **[1 mark]** • explains how the engineers have used their expertise in mechanics **[1 mark]** • explains how the engineers have used their expertise in control technology **[1 mark]** • includes one benefit to small businesses **[1 mark]** • includes a second benefit to small businesses **[1 mark]**

Q	Sample response	The response:
16	Polypropylene could be used for manufacturing a car bumper because it has high toughness, so it will be able to absorb the energy of an impact. It also has high tensile strength, so it will be able to withstand a lot of stress without breaking. Polyethylene could be used for manufacturing plastic food containers, such as frozen microwave meals, because it is able to withstand the temperatures of the microwave without deforming too much. It also has good chemical resistance, so it can be used for the storage of acidic foods.  	• identifies a suitable application for polypropylene **[1 mark]** • justifies the application by analysing the diagram and table to identify one relevant property **[1 mark]** • justifies the application by analysing the diagram and table to identify a second relevant property **[1 mark]** • identifies a suitable application for polyethylene **[1 mark]** • justifies the application by analysing the diagram and table to identify one relevant property **[1 mark]** • justifies the application by analysing the diagram and table to identify a second relevant property **[1 mark]** • appropriately annotates the diagram with an identified property of polypropylene or polyethylene **[1 mark]**

Q	Sample response	The response:
17a)	$VR = 4$	• correctly identifies velocity ratio from number of ropes in the system **[1 mark]**
17b)	Assume 100% efficiency $MA = VR$. $MA = \frac{F_L}{F_E}$ $F_E = \frac{500}{4}$ $= 125 \text{ N}$	• determines that $MA = VR$ **[1 mark]** • correctly calculates the effort **[1 mark]**

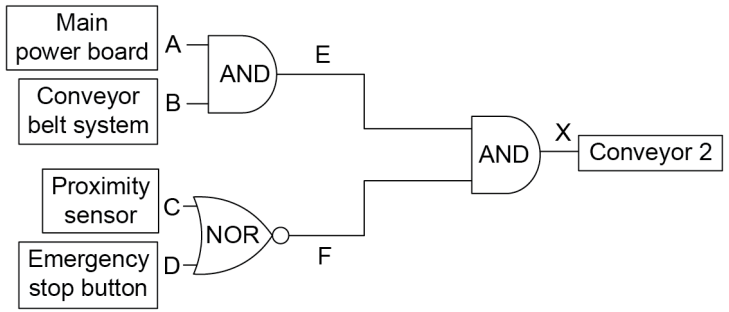
Q	Sample response	The response:
18a)	$\eta = \frac{MA}{VR}$ $MA = \eta VR$ $= 0.90 \times 16$ $= 14.4$ $MA = \frac{F_L}{F_E}$ $F_L = MA \times F_E$ $= 14.4 \times 20$ $= 288 \text{ N}$	• correctly calculates MA **[1 mark]** • calculates load force on the bottle opener **[1 mark]**
18b)	$VR = \frac{d_E}{d_L}$ $d_E = VR \times d_L$ $= 16 \times 2.5$ $= 40 \text{ mm}$ $= 0.04 \text{ m}$ $W = Fd$ $= F_E d_E$ $= 20 \times 0.04$ $= 0.8 \text{ J}$	• calculates distance of effort **[1 mark]** • calculates work done on the bottle opener to lift the bottle cap **[1 mark]**

Q	Sample response	The response:
19a)	38.1%	• correctly identifies the percentage of lead in the eutectic composition from the diagram **[1 mark]**
19b)	 $\% \text{ solid} = \frac{60-45}{83-45}$ $= \frac{15}{38}$ $= 0.39$ $= 39\%$ $\% \text{ liquid} = \frac{83-60}{83-45}$ $= \frac{23}{38}$ $= 0.61$ $= 61\%$	• correctly annotates the diagram to show intersection of 60% lead alloy at 200 °C **[1 mark]** • calculates the percentage of solid at 200 °C **[1 mark]** • calculates the percentage of liquid at 200 °C **[1 mark]**

Q	Sample response	The response:
20a)	Number of rotations of worm wheel in 2 m $= \frac{\text{linear distance}}{\text{circumference of wheel}} = \frac{2}{\pi d}$ $= \frac{2}{0.15\pi}$ $= 4.244$ rotations	• correct formula identified to calculate worm wheel rotations **[1 mark]** • correctly calculates the number of rotations of the worm wheel to raise the platform 2 m vertically **[1 mark]**

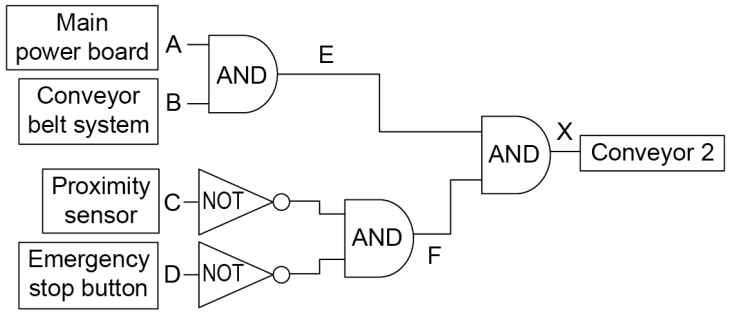
Q	Sample response	The response:
20b)	$W = F_L d_L$ $= mgh$ $= 250 \times 9.8 \times 2$ $= 4900 \text{ J}$	• calculates the work done at the lift to raise the combined mass to the maximum height of 2 m **[1 mark]**

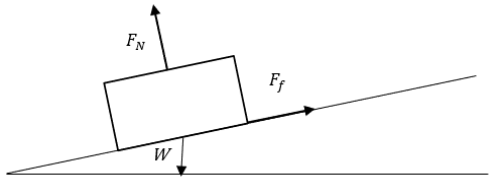
Q	Sample response	The response:
20c)	$P = \frac{W}{t}$ $= \frac{4900}{25}$ $= 196 \text{ W}$ $\eta = \frac{\text{useful power output}}{\text{power input}} \times 100$ $= \frac{196}{280} \times 100$ $= 0.7 \times 100$ $= 70\% \text{ efficiency}$	• correctly calculates the useful power output **[1 mark]** • calculates the energy efficiency of the platform lift **[1 mark]**

Q	Sample response	The response:
21	Method 1: NOR gate Logic gate circuit  	• provides a correctly applied logic gate circuit, including – main power board and conveyor belt system → AND1 → AND2 → conveyor 2 **[1 mark]** – proximity sensor → NOR → AND2 → conveyor 2 **[1 mark]** – emergency stop button → NOR → AND2 → conveyor 2 **[1 mark]** • correctly labels – main power board input and conveyor belt system input **[1 mark]** – proximity sensor input **[1 mark]** – emergency stop button input **[1 mark]** – power to conveyor 2 output **[1 mark]**

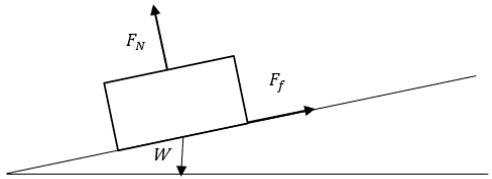
A	B	C	D	E	F	X
0	0	0	0	0	1	0
0	0	0	1	0	0	0
0	0	1	0	0	0	0
0	0	1	1	0	0	0
0	1	0	0	0	1	0
0	1	0	1	0	0	0
0	1	1	0	0	0	0
0	1	1	1	0	0	0
1	0	0	0	0	1	0
1	0	0	1	0	0	0
1	0	1	0	0	0	0
1	0	1	1	0	0	0
1	1	0	0	1	1	1
1	1	0	1	1	0	0
1	1	1	0	1	0	0
1	1	1	1	1	0	0

• correctly completes column E **[1 mark]**
• completes column X **[1 mark]**

Q	Sample response	The response:
21	Method 2: Proximity sensor and emergency stop inverted Logic gate circuit  See Method 1 for truth table.	• provides a correctly applied logic gate circuit, including – main power board and conveyor belt system → AND1 → AND3 → conveyor 2 **[1 mark]** – proximity sensor → NOT1 → AND2 → AND3 → conveyor 2 **[1 mark]** – emergency stop button → NOT2 → AND2 → AND3 → conveyor 2 **[1 mark]** • correctly labels – main power board input and conveyor belt system input **[1 mark]** – proximity sensor input **[1 mark]** – emergency stop button input **[1 mark]** – power to conveyor 2 output **[1 mark]** • correctly completes column E **[1 mark]** • completes column X **[1 mark]**

Q	Sample response	The response:
22	Method 1: Kinematics  	• includes an appropriate free-body diagram correctly showing all forces **[1 mark]**
	$F_N = F \perp$ $= mg\cos\theta$ $= 40 \times 9.8\cos 15$ $= 378.64 \text{ N}$	• correctly identifies that normal force is equal to the force perpendicular to the hill **[1 mark]** • correctly calculates the normal force **[1 mark]**
	$F_f = \mu_k F_N$ $= 0.35 \times 378.64$ $= 132.53 \text{ N}$	• calculates the frictional force **[1 mark]**
	$F_{\parallel} = mg\sin\theta$ $= 40 \times 9.8\sin 15$ $= 101.46 \text{ N}$	• calculates the parallel force **[1 mark]**
	$F_{net} = F_f - F_{\parallel}$ $= -132.53 + 101.46$ $= -31.07 \text{ N}$	• calculates the net force **[1 mark]**

Q	Sample response	The response:
	$F_{net} = ma$ $a = \frac{F_{net}}{m}$ $= \frac{-31.07}{40}$ $= -0.78 \text{ m/s}^2$ $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a}$ $= \frac{0^2 - 4^2}{2(-0.78)}$ $= 10.3 \text{ m}$	• calculates the acceleration **[1 mark]** • calculates the distance travelled downhill **[1 mark]**

Q	Sample response	The response:
22	Method 2: Energy  	• includes an appropriate free-body diagram correctly showing all forces **[1 mark]**
	$F_N = F \perp$ $= mg\cos\theta$ $= 40 \times 9.8\cos 15$ $= 378.64 \text{ N}$	• correctly identifies that normal force is equal to the force perpendicular to the hill **[1 mark]** • correctly calculates the normal force **[1 mark]**
	$F_f = \mu_k F_N$ $= 0.35 \times 378.64$ $= 132.53 \text{ N}$	• calculates the frictional force **[1 mark]**
	$F_{\parallel} = mg\sin\theta$ $= 40 \times 9.8\sin 15$ $= 101.46 \text{ N}$	• calculates the parallel force **[1 mark]**
	$F_{net} = F_f - F_{\parallel}$ $= -132.53 + 101.46$ $= -31.07 \text{ N}$	• calculates the net force **[1 mark]**

Q	Sample response	The response:
	Using principle of work and energy Work = change in kinetic energy $F_{net}d = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ $-31.07d = \frac{1}{2}(40)(4^2)$ $-31.07d = 320$ $d = \frac{320}{-31.07}$ $d = -10.3 \text{ m}$	• identifies that work is equal to the change in kinetic energy **[1 mark]** • calculates the distance travelled downhill **[1 mark]**

References

Question 11

Askeland DR, Wright WJ and Fulay PP (2011) The science and engineering of materials, 6th edn, Cengage Learning, Stamford

Callister WD and Rethwisch DG (2013) Materials Science and Engineering. An Introduction, 9th edn, Wiley, New York.

Question 19

Adapted from Lead Tin phase diagram (Fasediagram) by Woutervermeiren (2006) https://commons.wikimedia.org/wiki/File:Fasediagram_Pb_Sn.png
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