Engineering marking guide and response

External assessment 2023

Combination response (85 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 and a sample response.

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.

The sample response demonstrates the qualities of a high-level response.

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.

Where no response to a question has been made, a mark of 'N' will be recorded.

Allowing for FT error — 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 be awarded so long as it still demonstrates the correct conceptual understanding or skill in the rest of the response.

This mark may be implied by subsequent working — the full mathematical reasoning and/or working, as outlined in the sample response and associated mark, is not explicitly stated in the student response, but by virtue of subsequent working there is sufficient evidence to award the mark/s.

Rounding for results to intermediate steps in calculation questions are 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	C
3	A
4	D
5	B
6[1]	A and B
7	D
8	C
9	A
10	C

[1] The multiple-choice scrutiny panel reviewed the question and determined that there were two keys for this item.

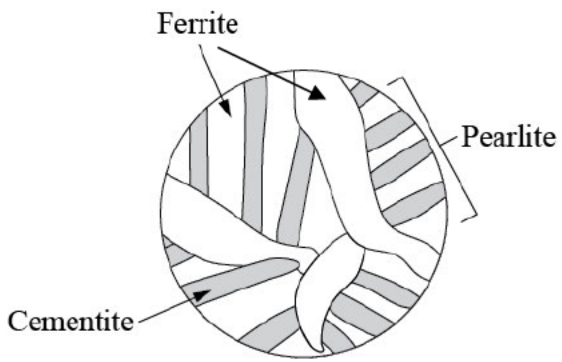
Short response

Q	Sample response	The response:
11	1. automobile bumper bar 2. electrical wall socket 3. face shield 4. hard hat	• provides a contemporary engineering application **[1 mark]** • provides a second contemporary engineering application **[1 mark]** • provides a third contemporary engineering application **[1 mark]** • provides a fourth contemporary engineering application **[1 mark]**

Q	Sample response	The response:
12	 When cycling up an incline, the cyclist will need a high mechanical advantage. The gear attached to the pedal arm that the cyclist pushes will need to be much smaller and have fewer teeth than the gear attached to the rear wheel. The smaller the pedal gear compared to the rear wheel gear, the higher the mechanical advantage and the easier it is for the cyclist to turn the pedals. As the gear attached to the pedals has a smaller circumference than the gear attached to the rear wheel it will need to make more rotations to get the bicycle to travel a greater distance. However, the work done by the cyclist remains the same, because while the force required to move the pedals will be less, the distance moved by the pedals will be more.	• appropriately explains the mechanical advantage, using wording that indicates – the pedal gear would be smaller than the rear wheel gear **[1 mark]** – work done remains the same **[1 mark]** – less force is required to move the pedals **[1 mark]** – more rotations of the pedals will be required **[1 mark]** • provides an appropriate sketch, including the larger rear wheel gear linked to the smaller pedal gear **[1 mark]**

<table>
<tr><th>Q</th><th>Sample response</th><th>The response:</th></tr>
<tr><td>13a)</td><td>
<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th>Q</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td></tr>
</table>
</td><td>• correctly completes column D [1 mark]
• correctly completes column E [1 mark]
• correctly completes column F [1 mark]
• correctly completes column Q [1 mark]</td></tr>
<tr><td>13b)</td><td>If the solar panel, wind turbine and timer are all on, the XOR gate will output 0 and only the solar panel will drive the electric motor because the XOR gate will prevent the wind turbine from operating the motor.
If the solar panel is off and the wind turbine and timer are on, the XOR gate will have an input of 0 and 1 and only the wind turbine will drive the electric motor.
If the wind turbine is off and the solar panel and timer are on, the OR gate will have an input of 1 and 1 allowing the solar panel to drive the electric motor.</td><td>• uses wording indicating that when all three inputs are on
– the solar panel drives the electric motor [1 mark]
– the XOR gate will not allow the wind turbine to drive the motor [1 mark]
• uses wording indicating that when
– the solar panel is off and the wind turbine and timer are on, the XOR gate allows the wind turbine to drive the motor [1 mark]
– the wind turbine is off and the solar panel and timer are on, the OR gate allows the solar panel to drive the motor [1 mark]</td></tr>
</table>

Q	Sample response	The response:
14	A mechanical engineer might explore similar problems involving machines that automatically press and move components from one location to another in the automotive manufacturing industry. They would determine solution success criteria to develop, test and evaluate ideas and a prototype, using knowledge of how metal is plasticly deformed into components, and how movement sensors control the function of automated stamping machines. A solution to the problem would then be manufactured and refined after evaluation of its function using success criteria.	• appropriately explains how a mechanical engineer might use the problem-solving process, using wording that indicates – phases of the problem-solving process in engineering ▪ explore **[1 mark]** ▪ develop or generate **[1 mark]** ▪ evaluate or refine **[1 mark]** – one area of engineering expertise **[1 mark]** – another area of engineering expertise **[1 mark]**

Q	Sample response	The response:
15a)		• provides an appropriate sketch of the microstructures that – clearly distinguishes between ferrite and pearlite **[1 mark]** – identifies ferrite **[1 mark]** – clearly distinguishes laminar structure of pearlite **[1 mark]** – identifies pearlite **[1 mark]**
15b)	The microstructures of medium carbon steel include grains of ferrite together with areas of very strong pearlite. The pearlite is a lamellar structure of soft, ductile ferrite and hard, brittle cementite. The amount of pearlite in the composition provides medium carbon steel with high strength and good toughness, which can withstand the heavy loads and repeated impact stresses that occur when trains are running on rails.	• appropriately explains medium carbon steel's usefulness as a material for train rails, referring to – the microstructures of medium carbon steel including lamellar or layered ▪ soft, ductile ferrite **[1 mark]** ▪ hard, brittle cementite **[1 mark]** – an appropriate mechanical property of medium carbon steel linked to use **[1 mark]** – a second appropriate mechanical property of medium carbon steel linked to use **[1 mark]**

Q	Sample response	The response:
16	$\mathrm{KE} = \frac{1}{2}\mathrm{mv}^2$ Storage container mass = $\frac{2\times \mathrm{KE}}{\mathrm{v}^2} = \frac{2\times 850}{1.5^2} = \frac{1700}{2.25} = 755.56\ \mathrm{kg}$ $\mathrm{PE} = \mathrm{mgh}$ $\mathrm{PE} = 755.56 \times 9.8 \times 2 = 14\,808.98\ \mathrm{J}$ $\mathrm{ME} = \mathrm{KE} + \mathrm{PE}$ $\mathrm{ME} = 850 + 14\,808.98$ $\mathrm{ME} = 15\,659\ \mathrm{J}$	• provides correct formula and substituted values for mass **[1 mark]** • determines mass **[1 mark]** • provides correct formula and substituted values for PE **[1 mark]** • determines PE **[1 mark]** • determines the answer in J to the nearest whole unit **[1 mark]**

Q	Sample response	The response:
17	PE= mgh 980= 40 x 9.8 x h $$h = \frac{980}{40 \times 9.8} = 2.5\text{ m}$$	• determines the vertical distance the load is raised **[1 mark]**
	$$VR = \frac{D_E}{D_L} = \frac{\pi D}{thread\ pitch} = \frac{\pi \times 30}{2.5} = 37.70$$	• provides correct formula and substituted values for VR of the thread mechanism **[1 mark]** • determines VR of the thread mechanism **[1 mark]**
	$$efficiency = \frac{MA}{VR}$$ MA=0.62 x 37.70 = 23.37	• determines MA **[1 mark]**
	$$\text{MA} = \frac{F_L}{F_E}$$ $$F_E = \frac{40 \times 9.8}{23.37} = 16.77\text{ N}$$	• determines effort **[1 mark]**
	Number of rotations of input shaft = $\frac{2.5\text{ m}}{0.0025} = 1000$	• determines rotations of shaft **[1 mark]**
	Distance travelled by effort = 1000 x π x 0.03 = 94.25 m	• determines distance effort **[1 mark]**
	W = Fd = 16.77 x 94.25 = 1580.57 J	• determines input Work **[1 mark]**
	$$P = \frac{W}{t} = \frac{1580.57}{15} = 105.4\text{ W}$$	• determines Input power **[1 mark]**

Q	Sample response	The response:
	OR Output Work is equal to 980 J of PE to load, thus output power $$P = \frac{W}{t} = \frac{980}{15}$$ $$= 65.33\ \mathrm{W}$$ Efficiency = output / input Input Power (motor power) = output / efficiency Input power = 65.33 / 0.62 = 105.37 W Input motor power = 105.4 W	**OR** • Identify that output work =change in PE **[1 mark]** • Correctly identify power equation **[1 mark]** • Correctly substitute into power equation **[1 mark]** • Correctly determine output power **[1 mark]** • Correctly identify efficiency equals output power/ input power **[1 mark]** • Correctly substitute into equation **[1 mark]** • Correctly determine input power **[1 mark]** • Correctly round to 1 decimal place **[1 mark]** • Correct unit for power **[1 mark]**

Q	Sample response	The response:
18a)	$VR = GR = \frac{d_E}{d_L} = \frac{number\ of\ teeth\ on\ driven}{number\ of\ teeth\ on\ driver} = \frac{8}{32} = 0.25$ Distance moved by bicycle wheel in 1 rotation of driven = $\pi D = \pi \times 0.7 = 2.199\ m$ Number of rotations of driven for 15m = $\frac{15}{2.199} = 6.82\ rotations$ $\therefore\ Number\ of\ rotations\ of\ driver = 6.82 \times 0.25 = 1.7$	• determines the VR / GR of the driven to driver gears **[1 mark]** • determines answer to one decimal place **[1 mark]**
18b)	Drive shaft rotations = Number of rotations of the driver gear = 1.7 ∴ The number of rotations of the drive shaft = 2	• correct interpretation of the mechanical system **[1 mark]** • determines answer to the nearest whole unit **[1 mark]**
18c)	Distance moved by motor drive shaft $= 2 \times \pi \times 0.02 = 0.126m$ $W = Fd = 600 \times 0.126 = 75.6\ J$ $P = \frac{W}{t} = \frac{75.6}{2} = 37.8\ W\ \approx 38\ W$ The output power of the electric motor is 38W	• determines the distance moved by the motor drive shaft **[1 mark]** • determines work **[1 mark]** • determines the answer in W to the nearest whole unit **[1 mark]**

Q	Sample response	The response:
19	Forces acting on the ramp $F_f = \mu F_N = \mu mg\cos\theta$ $F_f = 0.35 \times 2 \times 9.8 \times \cos25^o$ $F_f = 6.22\ \text{N}$	• determines the force of friction on the ramp **[1 mark]**
	Parallel force down the ramp $F_p = mg\sin\theta$ $F_p = 2 \times 9.8 \times \sin25^o$ $F_p = 8.28\ \text{N}$	• determines parallel force down the ramp **[1 mark]**
	Resultant force down the ramp $F_r = F_p - F_f$ $F_r = 8.28 - 6.22$ $F_r = 2.06\ \text{N}$	• determines resultant force down the ramp **[1 mark]**
	Acceleration down the ramp $F = ma$ $a = \frac{F}{m} = \frac{2.06}{2} = 1.03\ \text{m/s}^2$	• determines ramp acceleration **[1 mark]**
	Velocity at the bottom of the ramp $v^2 = u^2 + 2as$ $v^2 = 0.5^2 + 2 \times 1.03 \times 4$	• provides correct formula and substituted values for velocity **[1 mark]**
	$v^2 = 8.49$ $v = \sqrt{8.49}$ $v = 2.91\ \text{m/s}$	• determines velocity at the bottom of the ramp **[1 mark]**

Q	Sample response	The response:
	Horizontal surface $F_f = \mu F_N = \mu mg$ $F_f = 0.35 \times 2 \times 9.8 = 6.86\ N$ $F = ma$ $\text{Deceleration} = \frac{F}{m} = \frac{6.86}{2} = 3.43\ m/s^2$ Distance box slides along horizontal surface $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a}$ $s = \frac{0^2 - 2.91^2}{2 \times 3.43}$ $s = \frac{-8.47}{-6.86}$ $s = 1.235\ m$ The box slides 1.235 m along the horizontal surface before coming to a complete stop.	• determines force of friction on the horizontal surface **[1 mark]** • determines deceleration on the horizontal surface **[1 mark]** • determines the answer to the nearest whole unit **[1 mark]**

Q	Sample response	The response:
20	Uniform or constant velocity ∴ forces up incline = forces down incline	• indicates that the system is in equilibrium **[1 mark]**
	Let the coefficient of friction = μ_k 160 N = $\mathrm{F_f}$ + weight force component parallel to the incline	• identifies three forces parallel to the incline **[1 mark]**
	$160 = \mu_k F_N + \mathrm{mg}\sin 10$ $160 - \mathrm{mg}\sin 10 = \mu_k \times \mathrm{mg}\cos 10$ $160 - 20 \times 9.8 \times \sin 10 = \mu_k \times 20 \times 9.8 \times \cos 10$	• provides correct formula and substituted values **[1 mark]**
	$\mu_k = \dfrac{160 - 196 \times \sin 10}{196 \times \cos 10}$ $\mu_k = \dfrac{160 - 34.04}{193} = 0.65$	• correctly manipulates equation to isolate coefficient of friction **[1 mark]**
	∴ the coefficient of friction = 0.65	• determines the answer to two decimal places **[1 mark]**

Q	Sample response	The response:
21	First pump $W = \text{force} \times \text{distance} = Fd$ $W = mgh$ $W = 500 \times 9.8 \times 6$ $W = 29\ 400\ J$	• determines the work done by the first pump **[1 mark]**
	Power output: First pump $P = \frac{\text{work done}}{\text{time taken}} = \frac{W}{t}$ $P = \frac{29\ 400}{60}$ $P = 490\ W$	• determines the power output of the first pump **[1 mark]**
	Power input: First pump $\eta = \frac{\text{useful output}}{\text{input}}$ $\text{input} = \frac{\text{useful output}}{\eta}$ $\text{Power input} = \frac{490}{0.8}$ $\text{Power input} = 612.5\ W$	• determines the power input of the first pump **[1 mark]**
	Second pump $W = \text{force} \times \text{distance} = Fd$ $W = mgh$ $W = 500 \times 9.8 \times 4$ $W = 19\ 600\ J$	• determines the work done by the second pump **[1 mark]**

Q	Sample response	The response:
	Power output: Second pump $P = \frac{\text{work done}}{\text{time taken}} = \frac{W}{t}$ $P = \frac{19\,600}{60}$ $P = 326.67\ \text{W}$	• determines the power output of the second pump **[1 mark]**
	Power input: Second pump $\eta = \frac{\text{useful output}}{\text{input}}$ $\text{input} = \frac{\text{useful output}}{\eta}$ $\text{Power input} = \frac{326.67}{0.75}$ $\text{Power input} = 435.56\ \text{W}$	• determines the power input of the second pump **[1 mark]**
	Overall power input of two-pump system $\text{Power} = 612.5 + 435.56$ $\text{Power} = 1048.06\ \text{W}$	• determines the overall power input of the current two-stage system **[1 mark]**
	New single-pump system $\text{Power input} = 1048.06\ \text{W}$ $\text{Power output} = 90\% \times 1048.06$ $\text{Power output} = 943.25\ \text{W}$	• determines the power output of the new single-pump system **[1 mark]**

Q	Sample response	The response:
	New single-pump system: mass of water delivered per minute $P = \frac{W}{t}$ $W = P \times t$ $W = 943.25 \times 60$ $W = 56\,595\ \text{J}$	• determines the work done by the new single-pump system **[1 mark]**
	$W = mgh$ $m = \frac{W}{gh}$ $m = \frac{56\,595}{9.8\ \times 10}$ $m = 577.5\ \text{kg} = 578\ \text{litres per minute}$ ∴ The new single-pump system will deliver 578 litres of water per minute directly to the main reservoir.	• determines the answer in litres per minute to the nearest whole unit **[1 mark]**