Engineering marking guide and response

External assessment 2022

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
- has been annotated using the marking guide.

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.

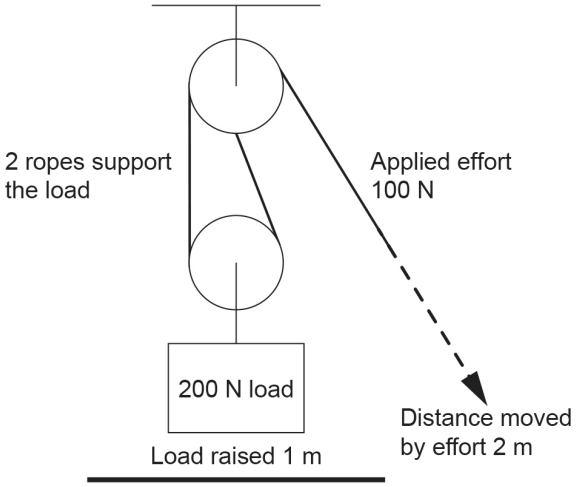
Rounding for results to intermediate steps in calculation questions are considered correct when provided within a range of two to a maximum of nine decimal places as determined using a scientific calculator. Final answers must be provided to the nearest whole unit or as otherwise stated in the question.

Marking guide

Multiple choice

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

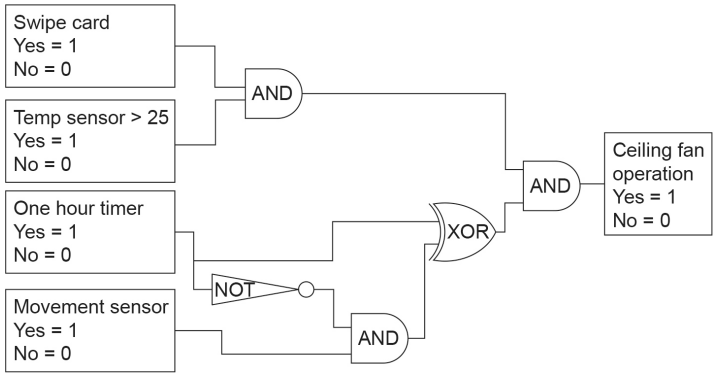
Short response

Q	Sample response	The response:
11	 For a pulley system with two ropes that support the load, the mechanical advantage (MA) is 2:1 as the effort required is half the load. The velocity ratio (VR) is 2:1 as this is the amount of rope pulled through the system divided by the distance the load is moved.	• explains MA appropriately using wording that indicates the number of ropes supporting the load proportionately reduces the effort required to move the load **[1 mark]** • explains VR appropriately using wording that indicates the distance moved by the effort divided by the distance the load is moved **[1 mark]** • provides an appropriately annotated sketch including – effort **[1 mark]** – load **[1 mark]** – distance moved by effort and load **[1 mark]**
12	1. Structural plates 2. Stampings 3. Forgings 4. Seamless tubes	• provides a correct industrial application **[1 mark]** • provides a second correct industrial application **[1 mark]** • provides a third correct industrial application **[1 mark]** • provides a fourth correct industrial application **[1 mark]**

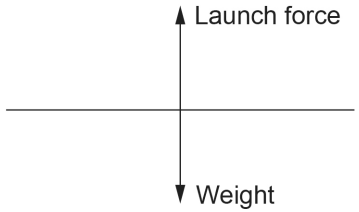
Q	Sample response	The response:
13	<table><tr><th>Input</th><th>Input</th><th>Output</th></tr><tr><td>0</td><td>0</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr></table> A NAND gate output is 0 when and only when all its inputs are at 1. Otherwise the output is 1.	• appropriately describes NAND gate function using wording that indicates the – output is 0 when all inputs are 1 **[1 mark]** – output is 1 when all inputs are not 1 **[1 mark]** • provides a truth table with – one column correct **[1 mark]** – a second column correct **[1 mark]** – a third column correct **[1 mark]**

Q	Sample response	The response:
14	I. solidus line: AEDC II. liquidus line: ABC III. eutectic point: B IV. eutectic temperature: 183º C V. maximum solubility of lead in tin: D VI. maximum solubility of tin in lead: E	• correctly identifies the – solidus line **[1 mark]** – liquidus line **[1 mark]** – eutectic point **[1 mark]** – eutectic temperature **[1 mark]** – maximum solubility of lead in tin **[1 mark]** – maximum solubility of tin in lead **[1 mark]**

Q	Sample response	The response:
15	The composition of mild carbon steel includes a higher amount of ferrite, providing ductility. The lower amount of pearlite in the composition still provides a high yield strength. High carbon steel includes a high amount of cementite compared to ferrite (in pearlite), contributing to a higher yield strength than mild carbon steel. The amount of cementite in the composition provides a less ductile material than mild carbon steel. Automotive subframes are subject to repeated stresses due to a range of loads caused by different road surfaces, conditions, loading and collision impacts. The very high yield strength and the lower ductility of high carbon steel produces lower toughness, which makes the material susceptible to fatigue cracking and less able to absorb the energy of repeated loading and collision impacts. The relatively high yield strength and good ductility of mild carbon steel provides high toughness that allows the frame to absorb the repeated loads and impacts. Therefore, mild carbon steel is more suitable than high carbon steel for use in the manufacture of automotive subframes.	• appropriately contrasts mild and high carbon steel and includes wording that indicates – the microstructure of mild carbon steel is ▪ higher in ferrite than high carbon steel **[1 mark]** ▪ lower in pearlite than high carbon steel **[1 mark]** – high carbon steel has a higher yield strength than mild carbon steel **[1 mark]** – high carbon steel is less ductile than mild carbon steel **[1 mark]** – mild carbon steel has better toughness than high carbon steel **[1 mark]** – mild carbon steel is a better material for automotive subframes, because of its higher toughness and ability to resist or absorb the repeated loads and impacts **[1 mark]**

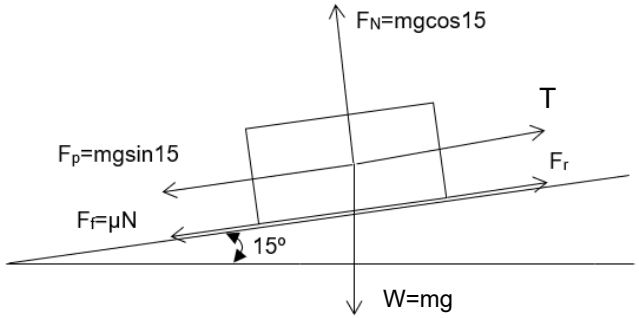
Q	Sample response	The response:
16		• provides a correctly applied logic circuit including – clearly identified swipe card input **[1 mark]** – clearly identified temperature input with temperature requirement >25 **[1 mark]** – clearly identified one-hour timer input **[1 mark]** – clearly identified movement sensor input **[1 mark]** – clearly identified ceiling fan operation output **[1 mark]** – swipe card and temp sensor => AND1 **[1 mark]** – condition 1 and condition 2 => AND2 => ceiling fan operation **[1 mark]** – one-hour timer => XOR => AND2 => ceiling fan operation **[1 mark]** – one-hour timer => NOT => AND3 => XOR => AND2 => ceiling fan operation **[1 mark]** – movement sensor => AND3 => XOR => AND2 => ceiling fan operation **[1 mark]**

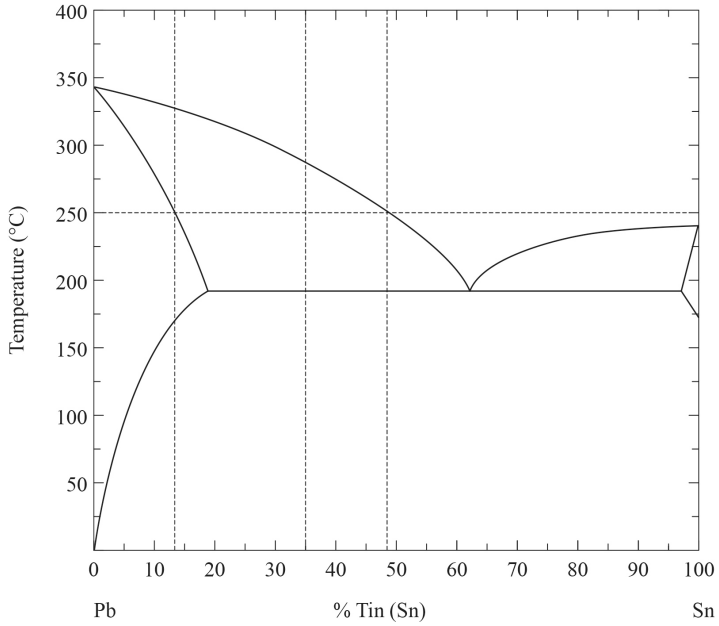
Q	Sample response	The response:
17	The stress–strain diagram indicates that the addition of ENR reduces the material's stiffness, tensile strength and toughness. However, the addition of ENR does increase elongation at break (plasticity) for all concentrations, although at 40% ENR plasticity is similar to nylon without ENR. The blending of ENR and nylon reduces nylon's effectiveness as a material for gear manufacture, because nylon gears must be reasonably stiff, strong and tough to resist deformation during use.	• explains appropriately using wording that indicates the inclusion of ENR at different percentages reduces nylon's – stiffness **[1 mark]** – tensile strength **[1 mark]** – toughness **[1 mark]** • explains appropriately using wording that indicates the inclusion of ENR at lower percentages increases nylon's plasticity **[1 mark]** • explains appropriately using wording that indicates the inclusion of ENR reduces nylon's effectiveness as a material for gear manufacture, with a reason provided **[1 mark]**

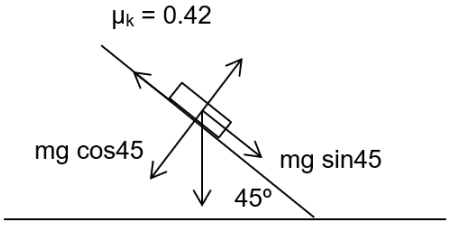
Q	Sample response	The response:
18	 $\text{Rocket weight} = 2000 \times 9.8 = 19\,600\ \text{N}$ $s = ut + \frac{1}{2}at^2$ $20\,000 = (0 \times 20) + \left(\frac{1}{2} \times a \times 20^2\right)$ $20\,000 = \frac{1}{2} \times a \times 20^2$ $\frac{40\,000}{400} = a = 100 m/s^2$ $F = ma$ $F_{net} = \text{launch force} - 19\,600 = 2000 \times 100$ $\text{Launch force} = 200\,000 + 19\,600 = 2019\,600\text{N}$ $\approx 220\ \text{kN}$ The rocket requires a launch force of 220 kN to reach a vertical height of 20 km in 20 s.	• provides an appropriate free-body diagram **[1 mark]** • correctly determines weight **[1 mark]** • provides correct formula and substituted values for acceleration **[1 mark]** • correctly determines acceleration **[1 mark]** • correctly determines the answer in kN to the nearest whole unit **[1 mark]**

Q	Sample response	The response:
19	$F_N = mg\cos\theta$ $F_N = 1500 \times 9.8 \times \cos 25 = 13\,322.72$ N $F_f = \mu F_N$ $= 0.01 \times 13\,322.72 = 133.23$ N	• correctly determines the initial frictional force **[1 mark]**
	$F_P = mg\sin\theta$ $F_P = 1500 \times 9.8 \times \sin 25 = 6212.49$ N	• correctly determines the force down the incline **[1 mark]**
	$F_{net} = 6212.49 - 133.23 = 6079.26$ N	• correctly determines the net force **[1 mark]**
	$F = ma$ $a = \frac{F}{m} = \frac{6079.26}{1500} = 4.1$ m/s^2 Brakes engage at 5 m/s $u = 2$ m/s $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a} = \frac{5^2 - 2^2}{2 \times 4.1} = 2.56$ m The cable car travels 2.56 m before the brakes engage.	• correctly determines the acceleration **[1 mark]** • correctly determines the displacement before brakes engage **[1 mark]**

Q	Sample response	The response:
	After braking: $F_f = \mu F_N$ $= 0.6 \times 13\,322.72 = 7993.63$ N $F_{net} = 6212.49 - 7993.63 = -1781.14$ N	• correctly determines the net force after brakes engage **[1 mark]**
	$F = ma$ $a = \frac{F}{m} = \frac{-1781.14}{1500} = -1.19\ m/s^2$	• correctly determines the deceleration after brakes engage **[1 mark]**
	$u = 5 m/s \quad v = 0\ m/s$ $v^2 = u^2 + 2as$ $s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 5^2}{2 \times -1.19} = 10.50$ m	• correctly determines the displacement after brakes engage **[1 mark]**
	Total distance travelled by the cable car after the cable fails = 2.56 +10.50 = 13.06 m ≈ 13 m ∴ The cable car stops 3 m after the warning siren activates.	• correctly determines the answer to the nearest whole unit **[1 mark]**

Q	Sample response	The response:
20		
	$\text{VR} = 3$ given $\text{Efficiency} = 80\%$ $\therefore \text{MA} = \frac{80}{100} \times \frac{3}{1} = 2.4$ $\text{mg} = 300 \times 9.8 = 2940 \text{ N}$ $\text{F}_\text{f} = 2940 \times 0.3 \times \cos 15 = 851.95 \text{ N}$ $\text{F}_\text{p} = 2940 \times \sin 15 = 760.93 \text{ N}$ $\text{F}_\text{total}\,(\text{T}) = 851.95 + 760.93 = 1612.88 \text{ N}$ $\text{MA} = \frac{\text{L}}{\text{E}}$ where $\text{L} = \text{T}$ $\text{E} = \frac{\text{L}}{\text{MA}} = \frac{1612.88}{2.4} = 672.03 \text{ N}$	• correctly determines MA **[1 mark]** • correctly determines mg **[1 mark]** • correctly determines the force of friction (F_f) **[1 mark]** • correctly determines the force parallel (F_p) **[1 mark]** • correctly determines the force total (T) **[1 mark]**
	The tension at E to almost begin moving the generator up the incline is 672.03 N.	• correctly determines the answer to two decimal places **[1 mark]**

Q	Sample response	The response:
21	 $\text{liquid} = \frac{35-13}{35} \times 100 = 63\%$ $\text{solid} = \frac{48-35}{35} \times 100 = 37\%$ Liquid is 48% tin and 52% lead $\therefore$ liquid tin at $250℃ = (0.48 \times 0.63) \times 100 = 30\%$ and liquid lead at $250℃ = (0.52 \times 0.63) \times 100 = 33\%$	• uses the diagram to – determine the area representing 65% lead and 35% tin **[1 mark]** – plot the percentage of liquid or solid at 250° C **[1 mark]** • correctly determines the percentage proportion of liquid **[1 mark]** • identifies the correct percentage of tin and lead as liquid at 250° C **[1 mark]** • correctly determines the percentage of the liquid components (tin and lead) **[1 mark]**

Q	Sample response	The response:
22		
	$F_{net} = ma = mg \times (\sin 45 - 0.42 \cos 45)$ $\therefore a = g \times (\sin 45 - 0.42 \cos 45)$ $= 9.8 \times (0.707 - 0.297) = 4.02\ m/s^2$	• correctly identifies the forces acting up and down the ramp in Section 1 **[1 mark]** • correctly determines the net force parallel to the ramp in Section 1 **[1 mark]** • correctly determines the acceleration down the ramp in Section 1 **[1 mark]**
	Using this acceleration down the steel ramp over 25 m and assuming an initial velocity of zero.	• provides one or more valid assumption/s **[1 mark]**
	$s = ut + \frac{1}{2}at^2$ $25 = 0 \times t + \frac{1}{2}4.02t^2$ $t^2 = \frac{50}{4.02}$ $t = \sqrt{12.438} = 3.53\ s$	• provides correct formula and substituted values for displacement **[1 mark]**

Q	Sample response	The response:
	Time taken for Section 1 = 3.53 s $\therefore 20 - 3.53$ = 16.47 s required for Section 2 and Section 3 Given that a ratio of 1:2 applies for travel on Sections 2 and 3 $\text{Section 3 time} = \frac{16.47}{3} \times 2 = 10.98 \text{ s}$	• correctly determines the time required to complete Section 1 **[1 mark]**
		• correctly determines the time required for Section 3 **[1 mark]**
	The velocity required in Section 3 is determined by: $v = \frac{s}{t} = \frac{30}{10.98} = 2.73 \text{ m/s}$	• correctly determines the velocity in Section 3 **[1 mark]**
	Given the diameter of the motor's driver roller is 250 mm: $\text{circumference} = \pi D = \pi \times 0.250 = 0.785 \text{ m}$ $\therefore \text{motor rpm} = \frac{2.73 \text{ m/s}}{0.785 \text{ m}} \times 60 = 208.66 \approx 209 \text{ rpm}$ ∴ the Section 3 variable speed motor must be adjusted to 209 rpm to transfer luggage from aircraft to carousel in 20 seconds.	• correctly determines the answer to the nearest whole unit with correct unit provided **[1 mark]**