Engineering marking guide and response

External assessment 2024

Combination response (79 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.

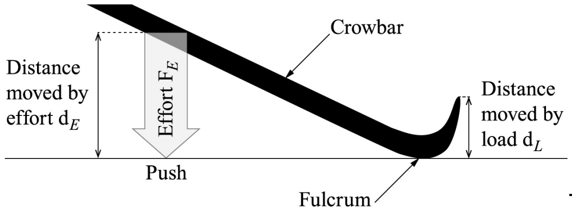
Rounding for results to intermediate steps in calculation questions is considered correct when provided within a range of two to a maximum of nine decimal places as determined using a scientific calculator. Final answers must be provided to the nearest whole unit or as otherwise stated in the question.

Marking guide

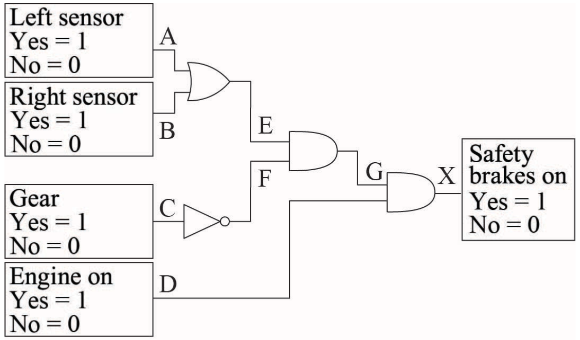
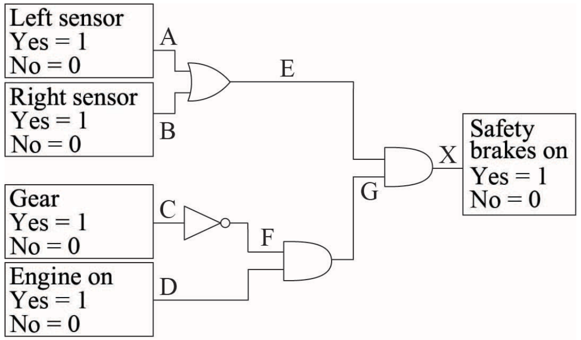
Multiple choice

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

Short response

Q	Sample response	The response:
11	 The purpose of a crowbar is to provide a mechanical advantage to reduce the effort (F_E) required to move a load (F_L) using a fulcrum. The crowbar provides mechanical advantage (*MA*) by dividing the force of the load by the force of the effort $MA = \frac{F_L}{F_E}$. When the fulcrum is closer to the load than the effort, the effort arm is longer and the crowbar has greater leverage, so the effort to move the load is reduced/amplified. The ratio between the distance moved by the effort (d_E) and the distance moved by the load (d_L) is referred to as the velocity ratio $VR = \frac{d_E}{d_L}$, which is a measure of how much a machine can amplify the effort applied to move the load.	• includes an appropriate sketch of a crowbar **[1 mark]** • explains the purpose of a crowbar appropriately, including wording relating to reduced/amplified effort force to move a load force **[1 mark]** • uses the concept of *MA* appropriately, including wording that indicates that as the length of the effort arm increases, the effort required to move the load reduces **[1 mark]** • uses the concept of *VR* appropriately, including wording that indicates the distance moved by the effort is divided by the distance the load is moved **[1 mark]**

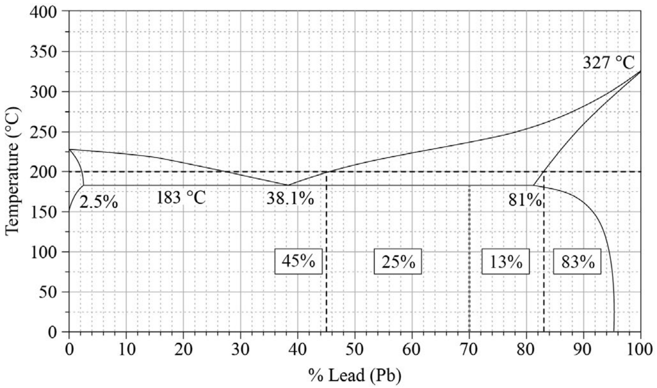
Q	Sample response	The response:
12	PVC is resistant to corrosive chemicals, making it more suitable for use in wastewater pipes in the home where it is likely to come into contact with corrosive chemicals, such as bleach or drain cleaner. Although polyethylene has greater heat resistance than PVC, the pipes won't be exposed to anything hotter than boiling water in the home so PVC will be good enough. PVC has a higher Young's modulus than polyethylene, which means it will be more rigid/less flexible, making it suitable for long lengths of pipe under the sink, floor or ground. PVC is cheaper than polyethylene as the manufacturing cost is lower. The combination of these properties makes PVC a more suitable material for use in the home.	• describes properties from the table appropriately using wording indicating – that PVC has greater chemical resistance than polyethylene **[1 mark]** – that polyethylene has better thermal properties so is more heat resistant than PVC, but this is not an important property for this application **[1 mark]** – that PVC is more rigid or less flexible than polyethylene **[1 mark]** – that PVC is cheaper than polyethylene **[1 mark]** • determines that PVC would be most suitable for wastewater pipes in the home **[1 mark]**
13	Application 1 An industrial application for high carbon steel could be springs because they need to have strength to resist deformation under the applied forces the spring will experience. A spring also needs to be wear/fatigue resistant for their springiness (compression/flexing during operation), so they can withstand repeated flexing without breaking. Application 2 Another industrial application could be cutting tools, such as dies, industrial knives or punches, because they need to be hard and very strong to cut or punch out shapes.	• identifies one suitable industrial application for high carbon steel **[1 mark]** • describes appropriately a mechanical property that makes it suitable for the application **[1 mark]** • describes appropriately a second mechanical property that makes it suitable for the application **[1 mark]** • identifies a second suitable industrial application for high carbon steel **[1 mark]** • describes appropriately a mechanical property that makes it suitable for the application **[1 mark]** • describes appropriately a second mechanical property that makes it suitable for the application **[1 mark]**

Q	Sample response	The response:
14	Mild carbon steel is suitable for seamless tubes due to its low carbon content. It is made up mainly of ferrite, which is a soft and ductile form of iron. This provides the material with ductility, which allows it to be formed into a tubular shape. Mild carbon steel also contains pearlite with small amounts of cementite. Cementite is hard and brittle, and excessive amounts can make a material too brittle to be formed. The small amount of cementite in mild carbon steel provides toughness, allowing the material to be shaped without fracturing.	• identifies that mild carbon steel is mostly made of ferrite **[1 mark]** • identifies that ferrite adds to the ductility of the material, which allows the material to be formed into shape **[1 mark]** • identifies that mild steel contains pearlite **[1 mark]** • identifies that pearlite (or cementite in pearlite) adds to the toughness of the material, which prevents fracturing **[1 mark]**
15	 **Method 1**	• provides a correctly applied logic gate circuit including – left motion sensor and right motion sensor => OR => AND1 => AND2 => safety brake operation **[1 mark]** – gear => NOT => AND1 => AND2 => safety brake operation **[1 mark]** – engine => AND2 => safety brake operation **[1 mark]** • correctly labels left and right motion sensor inputs **[1 mark]** • correctly labels gear input **[1 mark]** • correctly labels engine input **[1 mark]** • correctly labels intermediary inputs/outputs E, F and G **[1 mark]** • correctly labels safety brake output **[1 mark]**
	Method 2 	• provides a correctly applied logic gate circuit including – left motion sensor and right motion sensor => OR => AND2 => safety brake operation **[1 mark]** – gear => NOT => AND1 => AND2 => safety brake operation **[1 mark]** – engine => AND1 => AND2 => safety brake operation **[1 mark]** • correctly labels left and right motion sensor inputs **[1 mark]** • correctly labels gear input **[1 mark]** • correctly labels engine input **[1 mark]** • correctly labels intermediary inputs/outputs E, F and G **[1 mark]** • correctly labels safety brake output **[1 mark]**

Q	Sample response	The response:
16	Mechatronics engineers have used machines such as drones to benefit communities affected by flood events. Drones can be quickly deployed to survey flood-affected areas too dangerous for humans to access, assess damage, identify risks, e.g. submerged roads or fallen powerlines, and identify people who need to be rescued. Drones can also be used to get supplies to people until they can be safely rescued. Engineers have used their expertise with control technology to develop drones equipped with sensors, GPS and altitude controls that help to navigate and stabilise the drones during flight. They have used their expertise with materials science and mechanics to reduce the weight of drones and make them more aerodynamic, so they are more energy efficient.	• identifies the machine involved **[1 mark]** • describes a valid benefit for the community **[1 mark]** • describes a second valid benefit for the community **[1 mark]** • discusses how the engineers have used their expertise, including – a valid example from control technology **[1 mark]** – a valid example from materials science **[1 mark]** – a valid example from mechanics **[1 mark]**
17a)	$\sum F_y = 0$ $F_N = F_V$ $= mg\cos\theta$ $= 1300 \times 9.8\cos 25$ $= 11.55\ \text{kN}$	• correctly determines the method required to calculate the normal force **[1 mark]** • correctly calculates the normal force acting on the car **[1 mark]**

Q	Sample response	The response:
17b)	$\sum F_x = 0$ $F_s = F_H$ $= mg\sin\theta$ $F_s = \mu_s F_N$ $\mu_s = \frac{F_s}{F_N}$ $= \frac{mg\sin\theta}{mg\cos\theta}$ $= \frac{1300 \times 9.8\sin 25}{1300 \times 9.8\cos 25}$ $= 0.47$	• correctly determines the method required to calculate the coefficient of static friction **[1 mark]** • correctly calculates the coefficient of static friction required to prevent the car from rolling **[1 mark]**

Q	Sample response	The response:
18a)	Number of rotations $= \frac{150}{12}$ $= 12.5$ rotations Distance travelled for 12.5 rotations $d = 12.5 \times 2\pi r$ $= 12.5 \times 2 \times \pi \times 0.3$ $= 23.56\text{ m}$ Work done $W = F \times d$ $= 120 \times 23.56$ $= 2827.2\text{ J}$	• demonstrates appropriate mathematical reasoning to determine correct number of rotations **[1 mark]** • recognises that radius needs to be converted from mm to metres **[1 mark]** • calculates the distance travelled by the effort **[1 mark]** • calculates work done **[1 mark]**
18b)	Power $P = \frac{W}{t}$ $= \frac{2827.2}{180}$ $= 15.71\text{ W}$	calculates power input **[1 mark]**

<table>
<tr><th>Q</th><th>Sample response</th><th>The response:</th></tr>
<tr><td>19a)</td><td>


<table>
<tr><th></th><th>Solid</th><th>Liquid</th></tr>
<tr><td>Composition</td><td>83% Pb
17% Sn</td><td>45% Pb
55% Sn</td></tr>
<tr><td>Percentage</td><td>25/38 = 65.8%</td><td>13/38 = 34.2%</td></tr>
</table>
</td><td>

- annotates the diagram appropriately **[1 mark]**
- determines the composition of the solid from the tie line from the line of intersection at 200 °C in the solid phase = 83% Pb and 17% Sn **[1 mark]**
- determines the composition of the liquid from the tie line from the line of intersection at 200 °C in the liquid phase = 45% Pb and 55% Sn **[1 mark]**

</td></tr>
<tr><td>19b)</td><td>

Percentage solid at 200 °C

$= \frac{70-45}{83-45}$

$= \frac{25}{38}$

$= 65.8\%$

Percentage liquid at 200 °C

$= \frac{83-70}{83-45} = \frac{13}{38}$

$= 34.2\%$

</td><td>

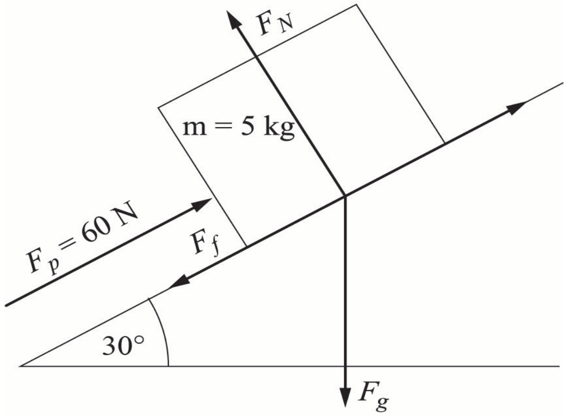
- determines the percentage solid at 200 °C **[1 mark]**
- determines the percentage liquid at 200 °C **[1 mark]**

</td></tr>
</table>

Q	Sample response	The response:
20	**Method 1** Forces perpendicular to the inclined plane are balanced, so $F_{\perp} = F_N$ $F_N = mg\ cos\theta$ $m = \frac{9.82}{9.8\ cos20}$ $m = 10.66\ \text{kg}$	• recognises that forces are balanced, therefore $F_{\perp} = F_N$ **[1 mark]** • recognises $F_N = mg\ cos\theta$ **[1 mark]** • correctly substitutes values **[1 mark]** • determines the mass of the parcel **[1 mark]**
	Method 2 When velocity is constant, acceleration = 0. ∴ forces parallel to the inclined plane are balanced, so $F \parallel = F_f$ $mg \sin\theta = \mu_k F_N$ $m = \frac{\mu_k F_N}{g \sin\theta}$ $m = \frac{0.37 \times 98.2}{9.8 \sin 20}$ $m = 10.84\ \text{kg}$	• recognises that forces are balanced, therefore $F \parallel = F_f$ **[1 mark]** • recognises $F \parallel = mg \sin\theta$ and $F_f = \mu_k F_N$ **[1 mark]** • correctly substitutes values **[1 mark]** • determines the mass of the parcel **[1 mark]**

Q	Sample response	The response:
21	$PE = mgh$ $= 1000 \times 9.8 \times 10$ $= 98 \text{ kJ}$ $E = KE + PE$ $106 = KE + 98$ $KE = 106 - 98$ $= 8 \text{ kJ}$ $KE = \frac{1}{2}mv^2$ $8000 = \frac{1}{2}1000v^2$ $v = \sqrt{\frac{2 \times 8000}{1000}}$ $= \sqrt{16}$ $= 4 \text{ m/s}$	• identifies that potential energy needs to be calculated first **[1 mark]** • correctly calculates the potential energy **[1 mark]** • recognises that total mechanical energy is equal to the sum of potential energy and kinetic energy **[1 mark]** • calculates the kinetic energy **[1 mark]** • identifies that velocity can be calculated from mass and kinetic energy **[1 mark]** • calculates the velocity **[1 mark]**

Q	Sample response	The response:
	$v^2 = u^2 + 2as$ $4^2 = 0^2 + 2a(10)$ $16 = 20a$ $a = \frac{16}{20}$ $a = 0.8\ \text{m/s}^2$	• identifies the correct formula for motion to calculate the acceleration **[1 mark]** • calculates the acceleration **[1 mark]**
	$v = u + at$ $4 = 0 + 0.8t$ $t = \frac{4}{0.8}$ $t = 5\ s$	• identifies the correct formula for motion to calculate the time **[1 mark]** • calculates the time **[1 mark]**

Q	Sample response	The response:
22	Not to scale  Horizontal component of weight $F\parallel = mg\sin\theta$ Vertical component of weight $F\perp = mg\cos\theta$ $F_N = F\perp$ $F_N = mg\cos\theta$ $= 5\times 9.8\times\cos 30$ $= 42.44\text{ N}$ $F_f = \mu_k F_N$ $= 0.58\times 42.44$ $= 24.62\text{ N}$	• includes an appropriate free-body diagram showing all forces **[1 mark]** • determines the normal force **[1 mark]** • determines the frictional force **[1 mark]**

Q	Sample response	The response:
	$F\parallel = mg\sin\theta$ $= 5 \times 9.8 \times \sin 30$ $= 24.5\ \text{N}$	• determines the parallel force **[1 mark]**
	$F_{\text{net}} = F_H - F\parallel - F_f$ $= 60 - 24.5 - 24.62\ \text{N}$ $= 10.88\ \text{N}$	• determines the net force **[1 mark]**
	$a = \frac{F}{m}$ $= \frac{10.88}{5}$ $= 2.18\ \text{m/s}^2$	• determines the acceleration **[1 mark]**
	$s = ut + \frac{1}{2}at^2$ $3 = 0t + \frac{1}{2}(2.18)t^2$ $6 = (2.18)t^2$ $t^2 = \frac{6}{2.18}$ $t = \sqrt{\frac{6}{2.18}}$	• demonstrates appropriate mathematical reasoning to calculate the time **[1 mark]**
	$t = 1.66\ \text{s}$ The object takes 1.66 s to travel 3 m up the incline.	• determines the time taken to displace the object 3 m up the incline **[1 mark]**

References

Question 14

Callister, WD Jr & Rethwisch, DG 2014, *Materials Science and Engineering: An introduction*, 9th ed., John Wiley & Sons, ch. 9, p. 338, figure 9.29. Used with permission.