Government of **Western Australia**
School Curriculum and Standards Authority

ENGINEERING STUDIES

ATAR course examination 2017

Marking Key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

Section One: Core content **40% (70 Marks)**

Part A: Multiple-choice **10% (10 Marks)**

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

Part B: Extended response **30% (60 Marks)**

Question 11 **(24 marks)**

(a) Calculate the internal radius of the tank, given that one litre is the same as 0.001 m^3. (4 marks)

Description	Marks
V = 360 × 0.001 = 0.36 m^3	1
r^2 = V/(π × length)	1
= 0.36/1.6 π	1
= 0.0716	
r = 0.268 m	1
Total	**4**

(b) Show that the energy needed to heat a full tank (360 L) of water from 22 °C to 76 °C is 81.2 MJ. (4 marks)

Description	Marks
Temperature change = (76 – 22)° = 54°	1
Heat = 4180 × 360 × 54	1-2
= 8.126 × 10^7 J	1
Total	**4**
Answer only receives zero marks. Working must be shown.	

(c) If the efficiency of such a hot water system using solar energy is 60%, how much solar energy must fall on the panels to heat a full tank of water? (2 marks)

Description	Marks
Solar energy = 81.26/0.6	1
= 135.43 MJ	1
Total	**2**

(d) The average effective solar irradiance in Perth on a given day in June on these panels is 2.96 kW m^{-2}. How many minutes would it take to heat a full tank of water from 22 °C to 76 °C? Assume 100% efficiency. (4 marks)

Description	Marks
Total solar irradiance = 2.96 × 4	
= 11.84 kW	1
Time = energy/power	
= 81200000/11840	1
= 6858 seconds	1
= 114 mins	1
Total	**4**

(e) On a very cloudy and cold day, the electric heater backup used 84.4 MJ of energy to bring the temperature of a full tank of water to the maximum 76 °C. How many kilowatt hours of electricity does this represent? (2 marks)

Description	Marks
1 kW hr = 1000 × 60 × 60 = 3600000 J	1
Number kW hr = 84400000/3600000	
= 23.44 kW hr	1
Total	**2**

(f) (i) Why are the panels placed at this set angle of 58° to the horizontal and not horizontally? (1 mark)

Description	Marks
Maximum average exposure to direct sunlight	1
Total	**1**

(ii) Why are the pipes and panel surfaces painted black? (1 mark)

Description	Marks
Better absorber of the Sun's radiation	1
Total	**1**

(g) Is a solar hot water system a renewable or non-renewable energy system? Give a reason for your answer. (2 marks)

Description	Marks
Renewable energy system	1
It is generated from natural sources that are replenishable	1
Total	**2**

(h) The government is encouraging more people to install solar hot water systems. State a positive environmental impact that this would have. (1 mark)

Description	Marks
Less greenhouse gases	1
Total	**1**
Accept other relevant answers	

Question 11 (continued)

(i) Suggest a metal **most** suited to being used for the edges and supports for the panels. (1 mark)

Description	Marks
Aluminium	1
Total	**1**
Accept other relevant answers	

(j) Give **two** reasons why you chose your answer to part (i) above. (2 marks)

Description	Marks
Lightweight	1
Corrosion resistant	1
Total	**2**
Accept other relevant answers	

Question 12 **(23 marks)**

(a) Calculate the total mass of the horizontal steel ribs. (5 marks)

Description	Marks
Length of ribs = 3.00 – 2 × 0.08	
= 2.84 m	1
Volume of ribs = 2.84 × 0.05 × 0.007 × 11	1
= 0.01093 m^3	1
Mass = density × volume	
= 7850 × 0.01093 kg	1
= 85.8 kg	1
Total	**5**

(b) What is the function of the vertical and horizontal ribs welded inside the frame? (1 mark)

Description	Marks
Add strength to the structure of the gate	1
Total	**1**
Accept any reasonable answer that suggests maintaining the structure **or** creating a barrier	

(c) Calculate the volume of steel in the bottom beam of the gate frame. (4 marks)

Description	Marks
External cross section area = 0.16 × 0.04	
= 0.0064 m^2	1
Internal cross section area = 0.152 × 0.032	
= 0.004864 m^2	1
Area of steel = external - internal	
= 0.0064 – 0.004864	
= 0.001536 m^2	1
Volume of steel = length × area	
= 3.00 × 0.001536	
= 0.004608 m^3	1
Total	**4**

(d) Give a structural reason why the hinges are bolted to a steel post and not directly to the brick pillar. Justify your answer. (2 marks)

Description	Marks
Reduces pressure at any one point on the brick pillar	1
Distributes the force load of the gate	1
Total	**2**
Accept answers that are similar or use bending moments	

Question 12 (continued)

(e) Give a possible problem caused by this mesh that made the gate difficult to open and a reason why the removal of the mesh solved this problem. (2 marks)

Description	Marks
Answers could include: The mesh increased the overall weight of the gate. Removal reduced the gates inertia allowing less force to open it **or** The mesh caused added air resistance. Removal allowed less force to be used.	1–2
Total	**2**
Accept other relevant answers	

(f) In the table below, list **four** other steps in the design process between the design brief and the final design and provide a short description of each. (8 marks)

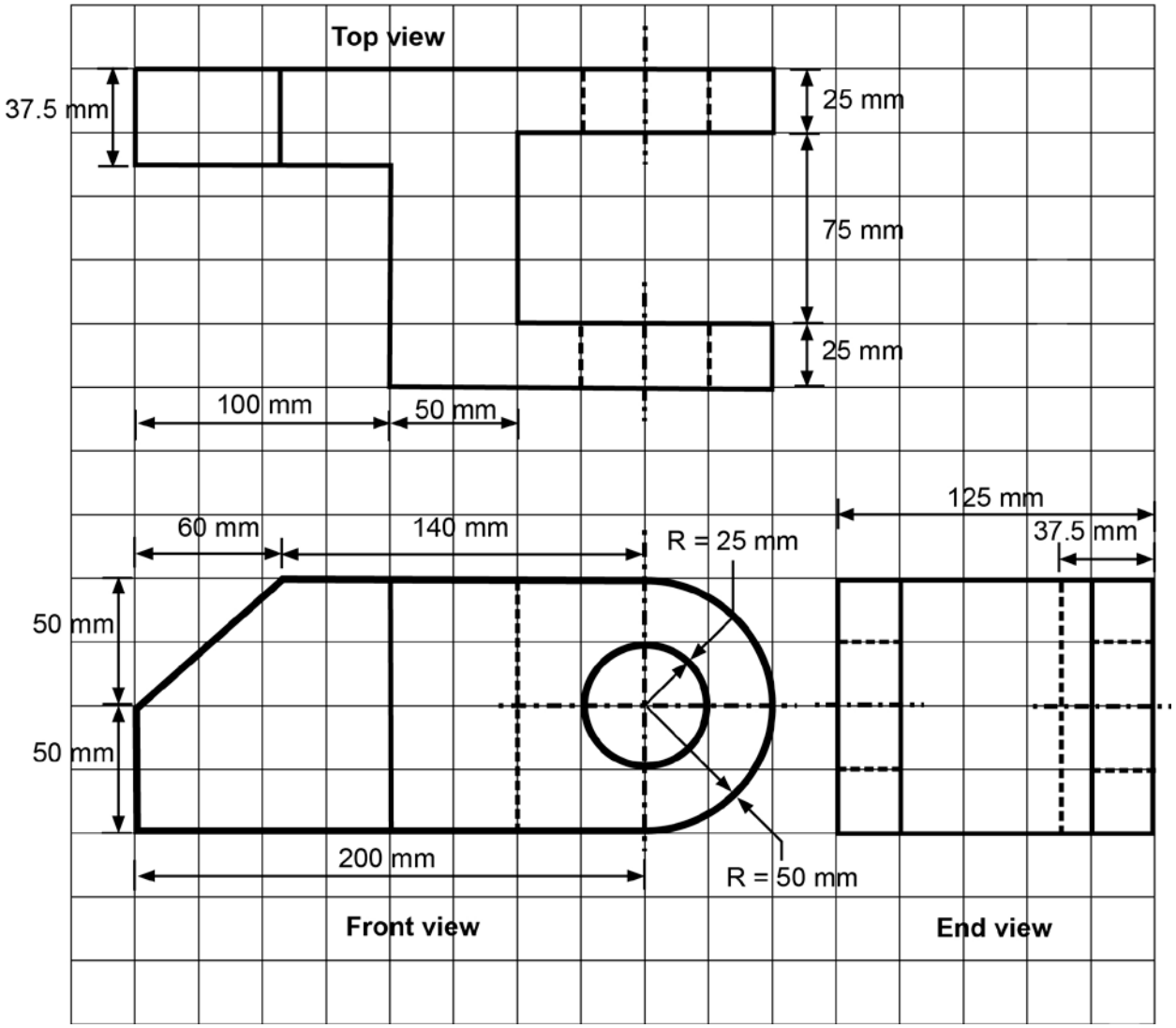
Description		Marks
Two marks for each step. One mark for step. One mark for description.		
Generate alternatives	Presents ideas and options to choose from	1–2
Analyse alternatives	Examine/test alternatives to decide on the best fit for the purpose based on design brief	1–2
Redesign	Modify the original design chosen if analysis suggests this is needed	1–2
Evaluate	Test the final design to determine it performs all requirements of the design brief	1–2
Total		**8**
Accept other relevant answers		

(g) At what stage in the design process should any problem with the mesh have been realised? (1 mark)

Description	Marks
Evaluate	1
Total	**1**

Question 13 **(13 marks)**

(a) On the grid provided on page 13 draw a scaled, labelled and dimensioned orthographic projection of this fitting, showing all **three** views. (11 marks)



Description	Marks
Three views correctly positioned	1
Suitable scale used and stated (grid 25 mm **or** one is to four)	1
Outlines of three views correctly drawn	1–3
Correct hidden detail for each view	1–3
Correct use of centre lines	1
Correct dimensioning format of linear features	1
Correct dimensioning format of circular features	1
Total	**11**

(b) What volume of metal, in cubic millimetres, was removed from the original block by the drill used to make the holes? (2 marks)

Description	Marks
Volume $= \pi r^2 \times$ length	1
$= \pi \times 25^2 \times 125$	
$= 245\ 437\ mm^3$ **or** $2.45 \times 10^{-4}\ m^3$	1
Total	**2**

Section Two: Specialised field—Mechanical 60% (110 Marks)

Part A: Multiple-choice 10% (10 Marks)

14	A
15	A
16	A
17	B
18	A
19	C
20	B
21	D
22	D
23	C

Part B: Extended answer 50% (100 Marks)

Question 24 (12 marks)

(a) Complete the following by circling the correct answer. (2 marks)

The top surface of the beam is under tension compression

The bottom surface of the beam is under tension compression

Description		Marks
Top	compression	1
Bottom	tension	1
	Total	**2**

(b) Calculate the second moment of area of the beam about its horizontal centroidal axis. (2 marks)

Description	Marks
$I_{xx} = \frac{bh^3}{12}$ $= \frac{70 \times 30^3}{12}$	1
$I_{xx} = 1.58 \times 10^5\ mm^4$	1
Total	**2**

(c) Calculate the maximum deflection in millimetres of the beam when the person stands at its centre. Convert your answer for maximum deflection to metres. (You can ignore the mass of the timber beam in your calculations.) (5 marks)

Description	Marks
Weight $F = mg$ $= 60 \times 9.8$ $= 588\ N$	1–2
$y = \frac{FL^3}{48EI}$ $y = \frac{0.588 \times 1500^3}{48 \times 12 \times 1.58 \times 10^5}$ $y = 21.81\ mm$	1–2
$y = 0.02181\ m$	1
Total	**5**

(d) If two people with the same mass stand in the middle of each of the beams as shown, which beam will have the greater maximum deflection? Circle your answer and provide an explanation (3 marks)

Description	Marks
Beam 2 is circled	1
Beam 2 has the smaller second moment of inertia (I_{xx}) as it has the smallest height (h)	1
As maximum deflection is equal to $y = \frac{FL^3}{48EI}$ reducing the second moment of inertial increases the maximum deflection	1
Note: Equation not essential in the answer but same logic is.	
Total	**3**

Question 25 **(26 marks)**

(a) Calculate the vertical reaction force at B. (3 marks)

Description	Marks
$F_B = F_{boom} + F_{tower} + F_{load} + F_{c/w}$ $= 1500 \times 9.8 + 1000 \times 9.8 + 70\,000 + 15\,000 \times 9.8$	1–2
$F_B = 241\,500\ N$	1
Total	**3**

(b) Calculate the reaction moment at B. State whether the moment is clockwise or anticlockwise. (4 marks)

Description	Marks
$M_B = F_{c/w} \times r_{c/w} - F_{boom} \times r_{boom} - F_{load} \times r_{load}$ $= 15\,000 \times 9.8 \times 4 - 1500 \times 9.8 \times 1 - 70\,000 \times 5$	1–2
$M_B = 223\,300\ Nm$	1
Clockwise	1
Total	**4**

(c) The winch now lifts the 70 kN load 2 m above the position shown in a time of 20 seconds.

(i) Calculate the change in potential energy of the load. (2 marks)

Description	Marks
$\Delta PE = F \times d$ $= 70\,000 \times 2$	1
$\Delta PE = 140\,000$ J	1
Total	**2**

(ii) Calculate the efficiency of the winch if it consumes 10 kW of electrical power while lifting the load. (4 marks)

Description	Marks
$P_{lift} = \frac{\Delta PE}{t}$ $= \frac{140\,000}{20}$	1
$P_{lift} = 7000\ W$	1
$\eta\% = \frac{P_{lift}}{P_{electical}} \times 100$ $\eta\% = \frac{7000}{10\,000} \times 100$	1
$\eta\% = 70\,\%$	1
Total	**4**

(d) Calculate the tensile force in the cable if it accelerates 1000 kg vertically upward at 1.5 m s^{-2}. (4 marks)

Description	Marks
$F = ma$ $T - W = ma$	1
$T = W + ma$ $= mg + ma$ $= 1000 \times 9.8 + 1000 \times 1.5$	1–2
$T = 11\,300\ N$	1
Total	**4**

(e) Applying a load to the cable causes it to increase in length from 4000 mm to 4008 mm. Calculate the strain in the cable. (3 marks)

Description	Marks
$\epsilon = \frac{\Delta L}{L}$ $= \frac{4008-4000}{4000}$	1–2
$\epsilon = 0.002$	1
Total	**3**

(f) Calculate the safe working stress of the cable if its ultimate tensile stress is 1000 MPa and the factor of safety is 2.5. (2 marks)

Description	Marks
$FS = \frac{\sigma_{UTS}}{\sigma_{safeworking}}$ $\sigma_{safeworking} = \frac{\sigma_{UTS}}{FS}$ $\sigma_{safeworking} = \frac{1000}{2.5}$	1
$\sigma_{safeworking} = 400\ MPa$	1
Total	**2**

(g) Name and justify **two** physical properties of steel that make it a suitable material for use in the manufacture of the cable. (4 marks)

Description	Marks
Two marks for each property and its justification	
Answers could include: • high ultimate tensile strength – allows heavy loads to be lifted without breakage	1–2
• high yield stress – allows heavy loads to be lifted without deformation.	1–2
Total	**4**
Accept other relevant answers	

Question 26 **(16 marks)**

(a) Show that the vertical reaction force at A is 11 000 N. (4 marks)

Description	Marks
At D $\Sigma M_{cw} = \Sigma M_{ccw}$ $F_A \times 6 = 1.0 \times 10^3 \times 6 \times \frac{6}{2} + 12 \times 10^3 \times 4$	1–3
$F_A = \frac{1.0\times10^3\times6\times\frac{6}{2}+12\times10^3\times4}{6}$ = 11 000 N	1
Total	**4**

(b) Determine the size of angle BAE. (1 mark)

Description	Marks
$\theta = \tan^{-1}\left(\frac{2}{2}\right)$ = 45°	1
Total	**1**

(c) Calculate the force in Member AE. (4 marks)

Description	Marks
At A, $\sum F_{vertical} = 0$ $F_A + F_{AE}\sin\theta = 0$ $F_{AE} = -\frac{F_A}{\sin\theta}$	1–2
$F_{AE} = -\frac{11\,000}{\sin 45}$	1
$F_{AE} = -$ 15 556 N (Accept negative or positive answer. Will depend on assumed direction of the applied force)	1
Total	**4**

(d) Is Member AE under compression or tension? Circle your answer below and provide an explanation. (3 marks)

Description	Marks
Compression is circled	1
Explanation could include: The vertical component of FAE opposes the reaction force FA This places the member into compression Accept other relevant answers	1–2
Total	**3**

(e) If the tension force in CF is 12 kN, calculate the stress in Member CF. (4 marks)

Description	Marks
$A = 0.150^2 - 0.134^2$	1
$A = 0.004544\ m^2$	1
$\sigma_{CF} = \frac{F}{A}$ $= \frac{12\times10^3}{0.004544}$	1
$\sigma_{CF} = 2.64\ MPa$	1
Total	**4**

Question 27 **(16 marks)**

The circular tube radius was incorrectly given in Q27. Marks awarded for either sets of data.

(a) Show that the total weight of the beam is 713 N. (5 marks)

Description		Marks
Uses radius of 150 mm/145 mm	**Uses radius of 75 mm/72.5 mm**	
$area = \pi r_{outside}^2 - \pi r_{inside}^2$ $= \pi \times 0.15^2 - \pi \times 0.145^2$ $= 0.004633\ m^2$	$= \pi \times 0.075^2 - \pi \times 0.0725^2$ $= 0.00115846\ m^2$	1–2
$volume = area \times length$ $= 0.004634 \times 2$ $= 0.009268\ m^3$	$= 0.00115846 \times 2$ $= 0.00231692\ m^3$	1
$mass = density \times volume$ $= 7850 \times 0.009268$ $= 72.8\ kg$	$= 7850 \times 0.00231692$ $= 18.188\ kg$	1
$W_{beam} = mass \times gravitational\ acceleration$ $= 72.8 \times 9.80$ $= 713\ N$	$= 18.188 \times 9.80$ $= 178.24\ N$	1
	Total	**5**

(b) Calculate the reaction force and moment at the fixed end A.

(i) Force (2 marks)

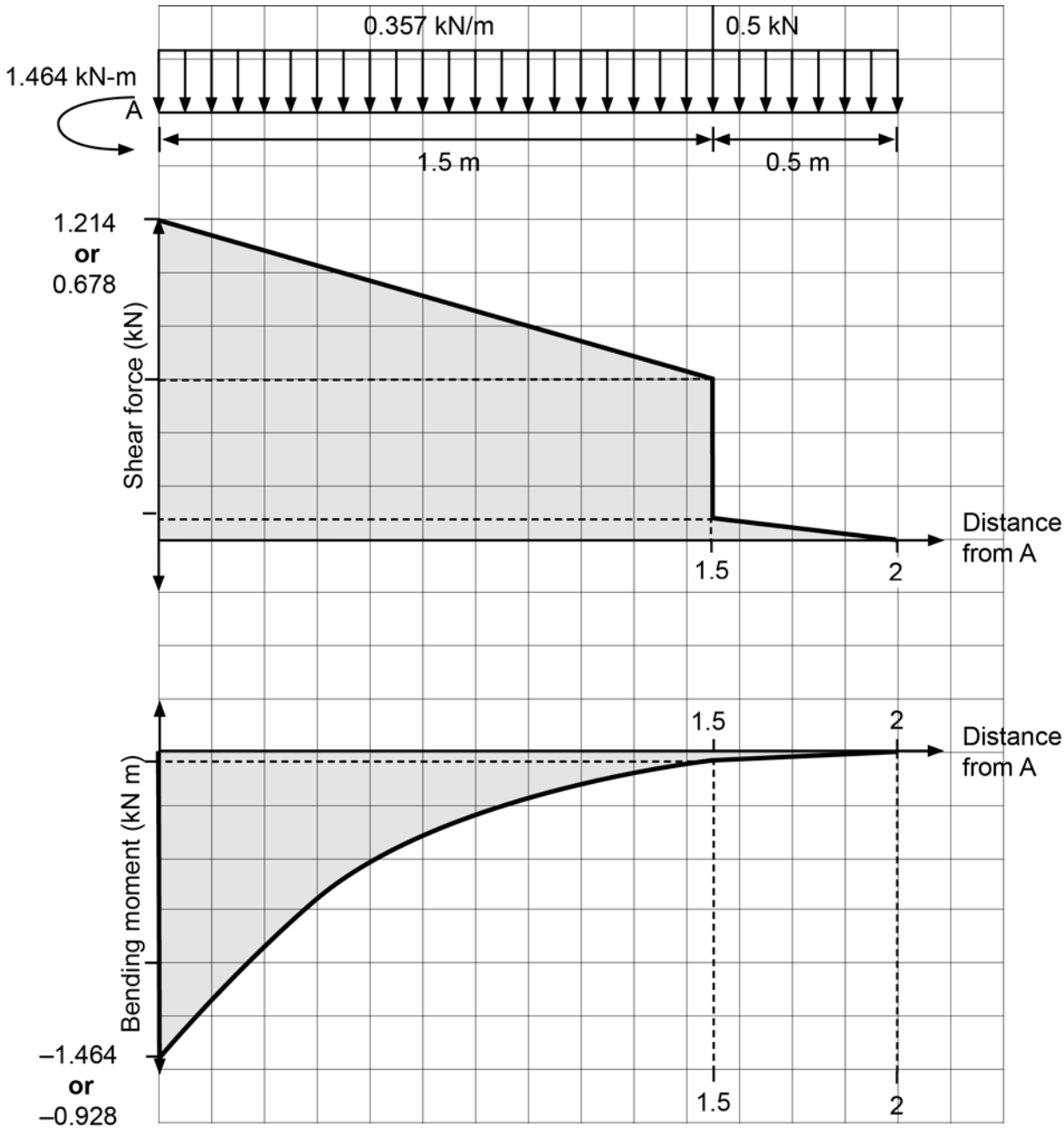
Description		Marks
Uses radius of 150 mm/145 mm	**Uses radius of 75 mm/72.5 mm**	
$F_A = W_{beam} + W_{sign}$ $= 713 + 500$	$= 178.24 + 500$	1
$F_A = 1213\ N$	$= 678.24\ N$	1
	Total	**2**

(ii) Moment (3 marks)

Description		Marks
Uses radius of 150 mm/145 mm	**Uses radius of 75 mm/72.5 mm**	
$M_A = W_{beam} \times L/2 + W_{sign} \times L$ $= 713 \times 2/2 + 500 \times (2 - 0.5)$	$= 178.24 \times 2/2 + 500 \times 1.5$	1–2
$M_A = 1463\ Nm$	$= 928.24\ Nm$	1
	Total	**3**

Question 27 (continued)

(c) Using the grid below, and taking into account all relevant forces, construct a shear force diagram and a bending moment diagram for the beam. (6 marks)



Description	Marks
Shear force	
Correct overall shape	1–2
Maximum shear force value labelled	1
Bending moment	
Correct overall shape	1–2
Minimum bending moment labelled	1
Total	**6**

Question 28 **(17 marks)**

(a) Calculate the mass of a spherical lead shot if it has a radius of 3 mm. Assume that the density of lead is 11 300 kg m^{-3}. (4 marks)

Description	Marks
$\mathrm{V} = \frac{4}{3}\pi r^3$ $= \frac{4}{3}\pi(0.003)^3$	1
$V = 1.13 \times 10^{-7}\ m^3$	1
$m = \rho V$ $= 11\ 300 \times 1.13 \times 10^{-7}$	1
$m = 1.28$ g or $1.28 \times 10^{-3}\ kg$	1
Total	**4**

(b) Calculate the time that a lead shot takes to drop to the bottom of the tower. (3 marks)

Description	Marks
$\mathrm{s} = \mathrm{ut} + \frac{1}{2}at^2$ $-25 = 0 \times t + \frac{1}{2} \times -9.8 \times t^2$ $t = \sqrt{-\frac{2\times25}{-9.8}}$	1–2
t = 2.26 s	1
Total	**3**

(c) Calculate the speed of a falling lead shot when it is at a height of 10 m above the base of the tower. (4 marks)

Description	Marks
s = 25 – 10 = 15 m	1
$v^2 = \mathrm{u}^2 + 2\mathrm{as}$ $= 0^2 + 2 \times -9.8 \times -15$ $v = \sqrt{2 \times -9.8 \times -15}$	1–2
$v = 17.1\ m\ s^{-1}$	1
Total	**4**

(d) A lead shot with a mass of 3 g is now dropped from the top of the tower. Calculate its height above the base of the tower when its kinetic energy is 0.59 J. (3 marks)

Description	Marks
$KE_1 + PE_1 = KE_2 + PE_2$ $0 + 0.003 \times 9.8 \times 25 = 0.59 + 0.003 \times 9.8 \times h$ $h = \frac{0.003\times9.8\times25-0.59}{0.003\times9.8}$	1–2
h = 4.93 m	1
Total	**3**

Question 28 (continued)

(e) This 3 g lead shot and another lead shot with a mass of 5 g were dropped from the tower at the same time. Did the 3 g lead shot or the 5 g lead shot hit the bottom of the tower first or did they hit at the same time? You can ignore the effects of air resistance.

(3 marks)

Circle your answer and provide an explanation.

3 g lead shot first 5 g lead shot first same time

Description	Marks
Same time is circled	1
Explanation The acceleration due to gravity on Earth is 9.8 m s^{-2} which is independent of mass **or** As the acceleration of both lead shots is the same they will both hit the floor at the same time	1–2
Total	**3**

Question 29 **(13 marks)**

(a) Calculate the force required to break the sample. (4 marks)

Description	Marks
$A = \pi \times 1.5^2 = 7.07\ mm^2$	1
$\sigma = \frac{F}{A}$ $F = \sigma \times A$ $= 50 \times 7.07$	1–2
F = 353 N	1
Total	**4**

(b) Calculate the length of the sample when a 300 N force is applied, given it is still in the elastic region. (5 marks)

Description	Marks
$E = \frac{FL}{A\Delta L}$ $90 = \frac{0.300 \times 50}{7.07 \times \Delta L}$ $\Delta L = \frac{0.300 \times 50}{7.07 \times 90}$	1–2
$\Delta L = 0.0236$ mm	1
$L = L_0 + \Delta L$ $= 50 + 0.236$	1
$L = 50.236$ mm	1
Total	**5**

(c) As the sample is stretched it begins to plastically deform. Define what is meant by plastic deformation in the context of material testing. (2 marks)

Description	Marks
Permanently deform the material	1
Without fracture **or** failure	1
Total	**2**

(d) Explain what happens to the material between Point A and Point B on the graph. (2 marks)

Description	Marks
Material has exceeded its elastic limit (or yield strength)	1
Material is permanently deformed	1
Total	**2**

Section Two: Specialised field—Mechatronics **60% (110 Marks)**

Part A: Multiple-choice **10% (10 Marks)**

30	B
31	D
32	C
33	A
34	B
35	C
36	B
37	C
38	A
39	D

Part B: Extended answer **50% (100 Marks)**

Question 40 **(17 marks)**

(a) What is the current through the 5Ω resistor? Give a reason why. (2 marks)

Description	Marks
Current is 1.8 A	1
Current through 5 Ω and R1 is the same (They are in series)	1
Total	**2**

(b) Calculate the current through the 12 Ω resistor. (2 marks)

Description	Marks
By Kirchhoffs Law 3 A -1.8 A - I = 0	1
I = 1.2 A	1
Total	**2**

(c) Show by calculation the potential difference displayed on the voltmeter. (2 marks)

Description	Marks
By Ohms Law 12 Ω × 1.2 A = V	1
= 14.4 V	1
Total	**2**

(d) Calculate the power dissipated in the 5 Ω resistor. (2 marks)

Description	Marks
Power = $I^2 R$ = $1.8^2 \times 5$	1
= 16.2 W	1
Total	**2**

(e) Calculate the value of Resistor R1. (3 marks)

Description	Marks
Voltage across 5 Ω and R1 is 14.4 V	1
By Ohms Law R=V/I 14.4/1.8 = 8 Ω	1
8 Ω - 5 Ω = 3 Ω	1
Total	**3**

(f) Calculate the value of Resistor R2. (3 marks)

Description	Marks
Circuit voltage is 24 V Circuit current is 3 A	1
Circuit resistance is 8 Ω Parallel resistors are 4.8 Ω	1
8 Ω - 4.8 Ω = 3.2 Ω	1
Total	**3**

(g) If the voltage of the 24 V battery was to drop to 19.6 V, calculate the new reading on the voltmeter. (3 marks)

Description	Marks
New voltage is 19.6 V. Resistances remain the same.	1
19.6/24 × 14.4 = 11.76 V	1–2
Total	**3**

Question 41 **(8 marks)**

(a) Name the type of energy transformation that occurs between the driven gear and the pump rod. (1 mark)

Description	Marks
Rotary to reciprocating (allow rotary to oscillating)	1
Total	**1**

(b) In the windmill diagram shown, the pinion gear has 14 teeth and the driven gear has 56 teeth. If the wind wheel shaft is turning at 146 rpm, calculate the velocity of the bull (driven) gear. (3 marks)

Description	Marks
Bull gear is 56 teeth, pinion gear is 14 teeth, ratio is 4:1	1
146 rpm / 4 = 36.5 rpm	1–2
Total	**3**

(c) If the pump rod has 165 upstrokes in one minute, calculate the velocity of the wind wheel shaft. (4 marks)

Description	Marks
Pump rod is 165 upstrokes so bull wheel has 165 revolutions	1
Bull gear to pinion gear ratio is 4:1	1
Pinion gear ratio is 165 × 4, wind wheel shaft is 660 rpm	1–2
Total	**4**

Question 42 **(10 marks)**

(a) State **two** advantages of using PWM in this circuit rather than lowering the voltage by resistance to control the motor speed. (2 marks)

Description	Marks
One mark for each advantage	
Advantages could include: • increased efficiency • maximum torque • soft starting.	1–2
Total	**2**
Accept other relevant answers	

(b) What is the design purpose of Resistor R1? (1 mark)

Description	Marks
R1 controls the frequency of the IC and therefore the duty cycle (pulse rate)	1
Total	**1**

(c) What is the design purpose of Transistor Q1? (1 mark)

Description	Marks
The transistor is a driver to handle motor current the IC cannot	1
Total	**1**

(d) What is the design purpose of Diode D3? (1 mark)

Description	Marks
The diode protects the transistor from back EMF	1
Total	**1**

(e) What is the reason for including Switch S1? (1 mark)

Description	Marks
The switch reverses polarity to the motor so changes its direction	1
Total	**1**

(f) A switch could be placed at the +12 V input. Explain the advantage of such a switch. (2 marks)

Description	Marks
Switch off motor	1
Without switching off the control circuit	1
Total	**2**
Accept other relevant answers	

(g) Complete the table below if R2 is 5% tolerance carbon resistor. (2 marks)

Description	Marks
Colour code – blue, grey, brown, gold	1
Maximum value – 714 Ω	1
Total	**2**

Question 43 **(25 marks)**

(a) In the sequence above **circle** each numbered stage that the elevator is almost certain to be unoccupied? (3 marks)

Description	Marks
One mark for each correct stage circled	
Stages 1, 2, 3, 10 and 11 are circled (only three are needed for maximum marks)	1–3
Total	**3**

(b) In the space below, draw a flow chart to show the operation of the elevator. Include the 630 kg weight check and the flashing warning light. (9 marks)

Description	Marks
One mark for each correct flow position	
Request for elevator to pick up passenger(s)	1
Door opens to allow passenger(s) in	1
Door will not close (or reopens) if weight exceeds 630 kg	1
Warning if weight exceeds 630 kg	1
Select destination floor	1
Door closes before moving to floor	1
Door opens at destination	1
Door then closes at destination after passenger(s) have disembarked	1
Elevator moves to ground floor if not requested for two minutes	1
Total	**9**

(c) (i) Calculate the ratio of the gearbox. (2 marks)

Description	Marks
Ratio = 3660/15	1
= 244:1	1
Total	**2**

(ii) Suggest a type of gearbox that would be best suited to this application. (1 mark)

Description	Marks
Worm and worm wheel **or** compound gear drive	1
Total	**1**

(iii) Calculate the input power to the motor. (2 marks)

Description	Marks
Voltage in is 300 VDC Current is 14 A	1
300 × 14 = 4.2 kW	1
Total	**2**

(iv) Calculate the efficiency of the motor and gearbox. (2 marks)

Description	Marks
Input power is 4.2 kW Gearbox power is 3.864 kW	1
3.864 / 4.2 × 100 = 92%	1
Total	**2**

(v) Name the type of motion transformation between the drive pulley and the elevator. (1 mark)

Description	Marks
Rotary to linear	1
Total	**1**

(vi) The counterweight is approximately 2000 kg. Justify this mass. (2 marks)

Description	Marks
The average of the empty load and the full passenger load is about 2000 kg	1
The downward mass and upward mass are close to equal hence the motor has to do little work	1
Total	**2**

(d) Besides the increased safety of these large PWM motors, list **three** other advantages over the high-voltage DC motors they have replaced. (3 marks)

Description	Marks
One mark for each advantage	
Answer could include: • they are smaller and lighter since they have no gearbox • they require less maintenance (no gearbox oil change) • they give greater control of elevator speed • easily programmed to change speeds unlike geared systems • use less power since it is not wasted in resistance. Accept other relevant answers	1–3
Total	**3**

Question 44 **(19 marks)**

(a) State the purpose of the DB9 connector. (1 mark)

Description	Marks
The DB9 connector is used to program the PIC	1
Total	**1**

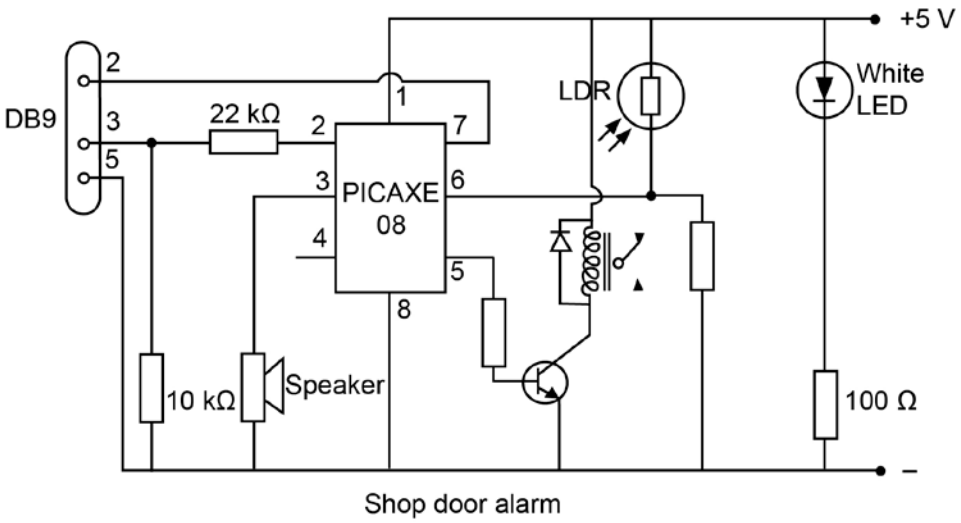
(b) State the specific type of input for pin 6 on the IC. (1 mark)

Description	Marks
Analogue input	1
Total	**1**

(c) The white LED draws 24 mA in this circuit. Calculate its operating voltage. (2 marks)

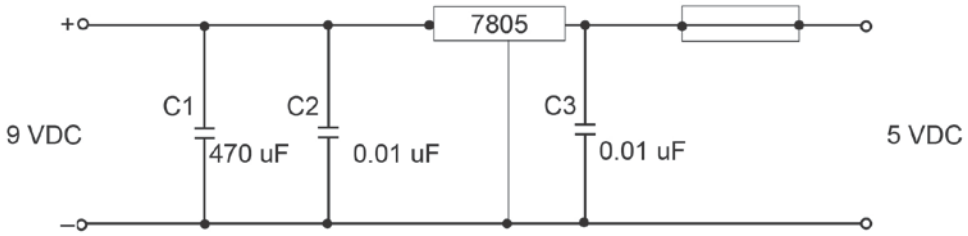
Description	Marks
Voltage across 100 Ω resistor = 100 × 0.024 = 2.4 V	1
Operating voltage 5.0 – 2.4 = 2.6 V	1
Total	**2**

(d) Complete the circuit below using additional components to show how a 5 V relay can be used. Values of the components do **not** have to be shown. (6 marks)

Description	Marks
One mark for correctly wiring in each of the following four components – resistor, transistor, relay and diode	1–4
One mark for correct diode polarity	1
One mark for connection of relay and diode to +5 V	1
 Shop door alarm	
Total	**6**

Note:
- students may use an NPN transistor or a Darlington pair
- relay and diode could also be on the emitter side of the circuit.

(e) The power supply needed to operate the shop door alarm is missing some components in the schematic. It requires an input 9 VDC voltage and the 5 V output should have a fuse. Label the voltage input, showing polarity and draw in the labelled components required to make a working circuit. (5 marks)

Description	Marks
Two marks for 9 V shown on the input and the polarity correct	1–2
Two marks for any 3 pin regulator could be used providing it is configured to produce 5 V. Drawn in correctly and labelled.	1–2
One mark for fuse drawn in correct space	1
	
Total	**5**

(f) Capacitor C3 has three numbers marked on it to indicate its capacitance. What are the numbers? (1 mark)

Description	Marks
103	1
Total	**1**

(g) What would the output voltage be? (1 mark)

Description	Marks
It remains at 5 V	1
Total	**1**

(h) What would be a suitable voltage rating for C1? (1 mark)

Description	Marks
Any answer above 12 V	1
Total	**1**

(i) Draw in a switch to the schematic in part (e) to turn the shop door alarm off. (1 mark)

Description	Marks
The switch can be drawn on the voltage input **or** the voltage output	1
Total	**1**

Question 45 **(21 marks)**

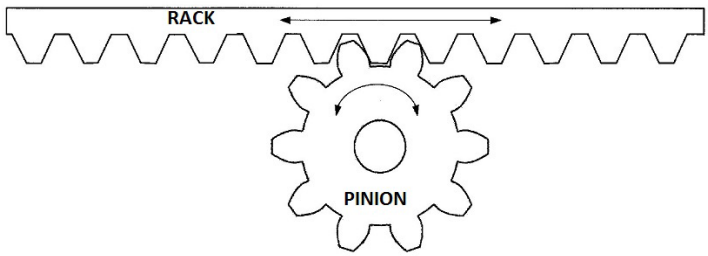
(a) Complete the table below to show the direction in which the vehicle will travel. (4 marks)

Description			Marks
Left motor motion	**Right motor motion**	**Direction that the vehicle will travel**	
Forward	Forward	Front **or** forward	1
Forward	Backward	Right	1
Backward	Forward	Left	1
Backward	Backward	Rear **or** backward	1
		Total	**4**

(b) Name the components are A, B and C1/C2 in the circuit shown. (3 marks)

Description		Marks
A	microcontroller	1
B	H drive IC (some candidates might name it as L293D IC)	1
C1/C2	motors	1
	Total	**3**

(c) State the common name given to this gear arrangement. On the basis of this name, label the parts on the diagram above. (2 marks)

Description	Marks
Name: Rack and Pinion	1
Correctly labels the parts 	1
Total	**2**

(d) Calculate the translation distance of the flat gear for **one** revolution of the circular gear. (2 marks)

Description	Marks
Pinion wheel has 10 teeth. Gear tooth pitch is 3 mm	1
Horizontal translation is 10 × 3 mm = 30 mm	1
Total	**2**

(e) If the circular gear was twice the diameter with the same gear pitch, what would be the translation distance for **two** revolutions of the circular gear? (2 marks)

Description	Marks
10 teeth on pinion. Twice diameter doubles the circumference so the number of teeth is doubled. i.e. 20	1
Two revolutions = 40 × 3 mm = 120 mm	1
Total	**2**

(f) By changing the diameter of the circular gear as described in part (e), would the mechanical advantage be greater or smaller? Give a reason for your answer. (2 marks)

Description	Marks
MA = VR and VR = distance moved by effort/distance moved by load	1
Since the distance moved by the effort (using rotations of the drive shaft connected to the pinion) is now reduced relative to the distance moved by the rack then MA is decreased.	1
Total	**2**

(g) Refer to the diagram shown on page 49. How many rotations of the circular gear would be required to provide a translation of 960 mm? (2 marks)

Description	Marks
960 mm on rack requires 320 × 3 mm pitch	1
The pinion has 10 teeth, 320/10 = 32 rotations	1
Total	**2**

(h) Complete the table below for a suitable mechanical drive system for each of the applications given. (4 marks)

Description		Marks
Application	**Drive system**	
Car alternator and water pump	Pulley belt	1
Car steering	Rack and pinion **or** worm and worm wheel	1
Bicycle propulsion	Chain and sprocket	1
Car gearbox	Compound gear drive	1
	Total	**4**

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ACKNOWLEDGEMENTS

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Published by the School Curriculum and Standards Authority of Western Australia
303 Sevenoaks Street
CANNINGTON WA 6107