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

ENGINEERING STUDIES

ATAR course examination 2016

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.

2016/65164

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

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

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

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

Question 11 **(14 marks)**

(a) Calculate the internal radius of the tank, given that its internal height is 3 m. (3 marks)

Description	Marks
$r^2 = V/\pi h$ $=20/3\pi$	1–2
$= 2.12$ $r = 1.4567$ m	1
Total	**3**

(b) State the energy changes in the

(i) pump when its electric motor is operating. (2 marks)

Description	Marks
Electrical to mechanical	1
Electrical to heat	1
Total	**2**
Accept any appropriate alternative answer.	

(ii) water as it is lifted from the bottom of the well to the tank. (1 mark)

Description	Marks
Potential to kinetic	1
Total	**1**
Accept any appropriate alternative answer.	

(c) Calculate the mass of water added when the tank refills from the bottom sensor to the top sensor. Note that 1 m^3 of water has a mass of 10^3 kg. (2 marks)

Description	Marks
m = 20 × (2.8/3.0) × 1000	1
= 18 667 kg	1
Total	**2**
Accept any relevant working that gets this answer.	

(d) The work required to lift enough water to fill the tank is 4.207 MJ. If the pump is rated at 750 W and is 85% efficient, how long will it take to refill the tank? (3 marks)

Description	Marks
0.85 × P = W/t t = W/0.85P	1
= 4.207 × 10^6/(0.85 × 750)	1
= 6599.2 s	1
Total	**3**

(e) How many kilowatt hours of electricity does the pump use to refill the tank five times? (2 marks)

Description	Marks
E = Pt = (0.75 × 6599.2 × 5)/60^2 kW hr	1
= 6.874 kW hr	1
Total	**2**

(f) Given that the efficiency of the electric pump is 85%, what happens to most of the other 15% of the energy provided to the pump? (1 mark)

Description	Marks
Heat (friction)	1
Total	**1**

Question 12 **(10 marks)**

(a) Calculate the mass of polycarbonate in the tank, including the base and the top. Ignore the circular ribs. (5 marks)

Description	Marks
$V_{TOTAL} = V_{TOP} + V_{BASE} + V_{SIDE}$	1
$= \pi r^2 + \pi r^2 + \pi(R^2 - r^2)h$	
$= 2(\pi \times 2.215^2 \times 0.015) + \pi(2.215^2 - 2.2^2) \times 2.80$ m^3	1
$= 0.4624 + 0.5825$ m^3	
$= 1.04$ m^3	1
$M = D \times V$ $= 1200 \times 1.04$ $= 1248$ kg	1 1
Total	**5**
Use discretion in part marking as students may follow an alternate route to the answer. Accept any appropriate alternative answer.	

(b) What is the purpose of these ribs? (1 mark)

Description	Marks
Give strength (rigidity) to the sides.	1
Total	**1**

(c) Suggest a shape for the lid that would give it extra strength. (1 mark)

Description	Marks
Conical or hemispherical	1
Total	**1**
Accept any appropriate alternative answer.	

(d) State an advantage of using plastic to manufacture such a tank, and state a property of polycarbonate that gives this advantage. (2 marks)

Description		Marks
ADVANTAGE:	long life	1
REASON:	non corrosive	1
Total		**2**
Accept any other relevant answers.		

(e) The manufacturers incorporated an ultraviolet-resistant additive in the polycarbonate used to make the tank. What problem would arise if this was **not** added to the polycarbonate? (1 mark)

Description	Marks
Limited life as plastic would break down	1
Total	**1**
Accept any appropriate alternative answer.	

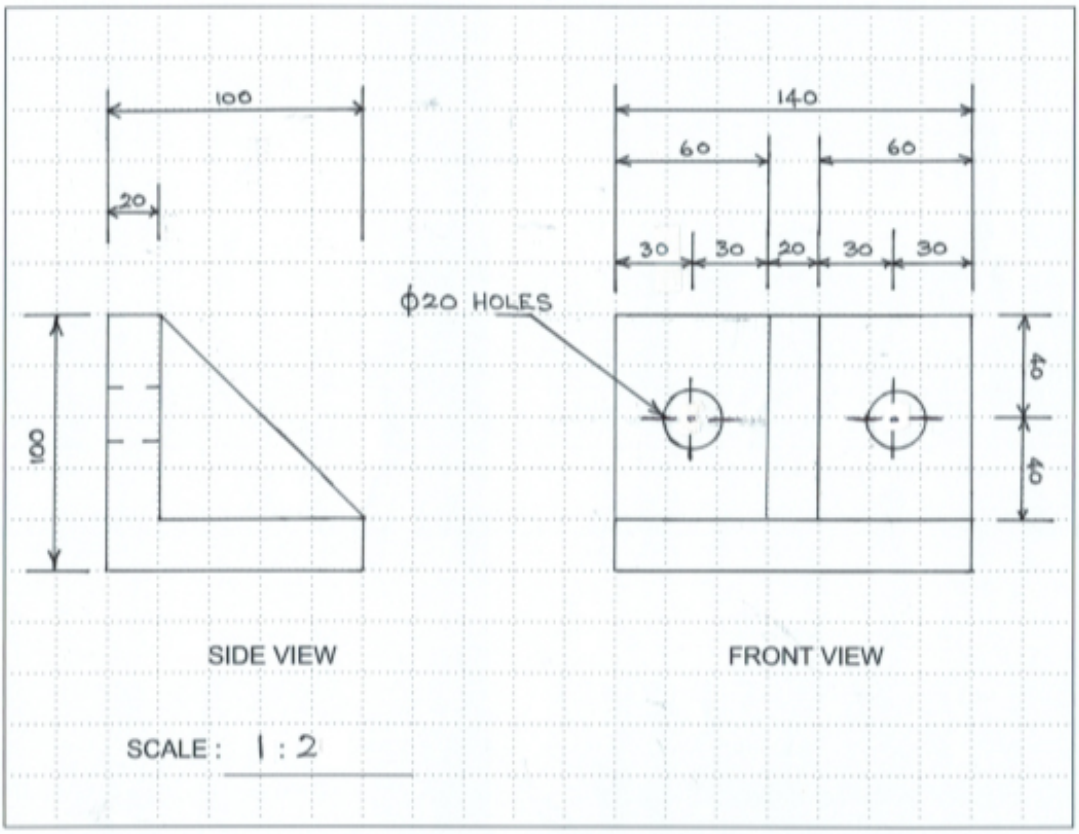
Question 13 **(17 marks)**

Using the grid provided on page 11, produce fully-dimensioned scalded orthographic drawings (front and side views) to enable a workshop to manufacture the bracket.

(a) You must ensure:

- your projections are neat and labelled. (4 marks)
- you have chosen a suitable scale and stated it. (2 marks)
- the correct relationship between the two views is shown. (1 mark)
- all hidden edges are shown correctly. (1 mark)
- all dimensions are shown correctly. (3 marks)

Description	Marks
All lines correct, 2 marks. All correct but one, 1 mark	1–2
Views match labels and orientations correct	1
Holes shown correctly and labelled	1
Scale stated.	1
Scale suitable to fit drawing onto page for maximum size as per answer sheet.	1
The two views are shown in line with each other.	1
Hidden edges of holes shown correctly.	1
All dimensions are shown correctly, 2 marks. All correct but one, 1 mark.	1–2
Hole is dimensioned correctly	1
Total	**11**



(b) (i) Calculate the volume of this metal bracket, ignoring the holes. (3 marks)

Description	Marks
V = V of L shape + V of triangle = Area of L × length + Area of triangle × width	1
= [(0.002 + 0.016) × 0.14] + (0.5 × 0.08 × 0.08 × 0.02) = 0.000 504 + 0.000 064 m^3	1
= 0.000 568 or 5.68 × 10^{-4} m^3	1
Total	**3**
Use discretion in part marking as candidates could follow an alternate route to the answer. Accept any relevant techniques for part marks.	

(ii) The bracket is to be made of stainless steel. Calculate its mass. (2 marks)
(If you did not obtain an answer for (i) above use a volume of 6.5 × 10^{-5} m^3.)

Description	Marks
$M = D \times V$	1
= 7600 × 0.000 568 kg = 4.316 8 kgg	1
Total	**2**
Alternative answer if 6.5 × 10^{-5} m^3 used = 0.494 kg or 494 g.	

(c) Using your Data book, state a possible advantage of using stainless steel rather than structural steel to make this bracket. (1 mark)

Description	Marks
Non corrosive	1
Total	**1**
Accept any other suitable answer that is based on the Data book.	

Question 14 **(19 marks)**

(a) Explain why reinforced concrete is used to construct the footings for the towers rather than concrete that is **not** reinforced. (2 marks)

Description	Marks
Reinforcing rods in reinforced concrete give it greater strength under tension (bending forces). (or similar wording)	1–2
Total	**2**
Accept any appropriate alternative answer.	

(b) Explain why each concrete footing is significantly wider than the base of the tower it supports. (2 marks)

Description	Marks
REASON 1: Allows for larger torque (bending moment) at the edges. EXPLANATION 1: $\tau = Fr$, increase r increases torque	1–2
or	
REASON 2: Increased surface area of base EXPLANATION 2: Larger area reduces pressure on the ground. $P = F/A$	1–2
Total	**2**
Accept any appropriate alternative answer.	

(c) Including the base of the tower, 40% of the volume of each footing is structural steel. Calculate the mass of **one** such footing. (3 marks)

Description	Marks
$M = D \times V$ $= (0.4 \times 7850 + 0.6 \times 2400) \times \pi \times (15.4/2)^2 \times 2.60$	1–2
$= 2.218 \times 10^6$ kg or 2 218 tonne	1
Total	**3**

(d) Calculate the volume of steel in the cylindrical steel base that supports the upper part of each tower. (4 marks)

Description	Marks
Inner radius = (4.20/2) – 0.036 = 2.064 Thickness = $R^2 - r^2 = 2.10^2 - 2.064^2 = 0.150$ m^2	1–2
Volume = $\pi(R^2 - r^2)h$ $= \pi \times 0.01499 \times 2$	1
$= 0.94187$ m^3	1
Total	**4**

(e) The tip of each blade rotates in a circular path.

(i) Calculate the circumference of this path. (2 marks)

Description	Marks
Circumference = $2\pi r$ $= 2 \times \pi \times 35.5$	1
$= 223.05$ m	1
Total	**2**

(ii) Calculate the speed in metres per second of the tip of each blade when it is rotating at 21.5 rpm. (3 marks)

Description	Marks
Period(T) = 60/21.5 = 2.791 s	1
Velocity = circumference/period = $2\pi r/T$ = 223/2.791	1
= 79.9 m s^{-1}	1
Total	**3**

(f) One wind farm has six generators, each with a maximum electrical output of 2300 kW. If each generator produces 40% of its maximum output in a year, how many kilowatt hours of electricity would the farm produce in that time? (2 marks)

Description	Marks
E = 40% × P × t × 6 = 0.4 × 2300 × 365 × 24 × 6	1
= 48 355 200 kW hr	1
Total	**2**

(g) What major environmental advantage does wind generation have over the use of fossil fuels to generate electricity? (1 mark)

Description	Marks
No greenhouse gasses produced.	1
Total	**1**
Accept any appropriate alternative answer.	

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

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

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

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

Question 25 **(10 marks)**

(a) Show that the weight of the hammer head is 256.96 N. (3 marks)

Hint: density = $\frac{\text{mass}}{\text{volume}}$

Description	Marks
Mass = density × volume = 8740 × 0.1 × 0.1 × 0.3 = 26.22 kg	1
Weight = mass × g = 26.22 × 9.8 = 256.956 N	1–2
Total	**3**

(b) When the hammer is balanced on the end of its handle as shown above, the weight of the head compresses the handle and reduces its length. Show by calculation that this change in length is close to zero. Assume that only the weight of the head affects the length of the handle. (7 marks)

Description	Marks
Converts length to mm	1
Converts area to mm^2	1
Converts E to N mm^{-2} (or weight to kN)	1
Selects appropriate formula or formulae	1
Calculates ΔL	1–3
Total	**7**
Example calculation: L = 0.6 m = 600 mm A = 12 cm^2 = 1200 mm^2 E = 90 × 10^3 N mm^{-2} $E = \frac{FL}{A\Delta L}$ $\therefore \Delta L = \frac{FL}{AE} = \frac{(256.96)(600)}{(1200)(90 \times 10^3)}$ = 0.00123 mm … which is close to zero	

Question 26 **(10 marks)**

(a) Calculate the Young's modulus of Material B from the graph. (4 marks)

Description	Marks
E = gradient of graph	1
= stress / strain = (100 – 0)/(0.9 – 0)	1–2
= 111 kN mm^{-2}	1
Total	**4**
Accept any other suitable points from the graph. The calculated value should be between 100 and 120 kN mm^{-2}	

(b) Using the information from your Data book, answer the following questions relating to this graph.

(i) Which material is likely to be copper? (1 mark)

Description	Marks
B	1
Total	**1**

(ii) Give **three** reasons for your answer. (3 marks)

Description	Marks
Gives three valid reasons, 1 mark each	1–3
Total	**3**
Answers could include: • Young's modulus close to value in Data book • Yield stress close to value in Data book • Ultimate tensile stress close to value in Data book • Huge plastic deformation	

(c) The area under the graph of Material B is divided into sections labelled 'Y' and 'Z'. What material properties do the following represent?

(i) Area Y: (1 mark)

Description	Marks
resilience	1
Total	**1**

(ii) Area Y + Area Z: (1 mark)

Description	Marks
toughness	1
Total	**1**

Question 27 **(21 marks)**

(a) Calculate R_A, the reaction force at A. (4 marks)

Description	Marks
Taking moments about B Clockwise moment = anti clockwise moment	1
9.80 × 150 × (0.2 + 0.5) = R_A × 1.5	1–2
R_A = 686 N (upward)	1
Total	**4**

(b) Calculate R_B, the reaction force at B. (2 marks)

Description	Marks
Force upward at B $R_A + R_B = 150 \times 9.8$ $R_B = 1470 - 686$	1
= 784 N (upward)	1
Total	**2**

(c) (i) Describe how to calculate the shear force at Point X, the midpoint of the beam. (3 marks)

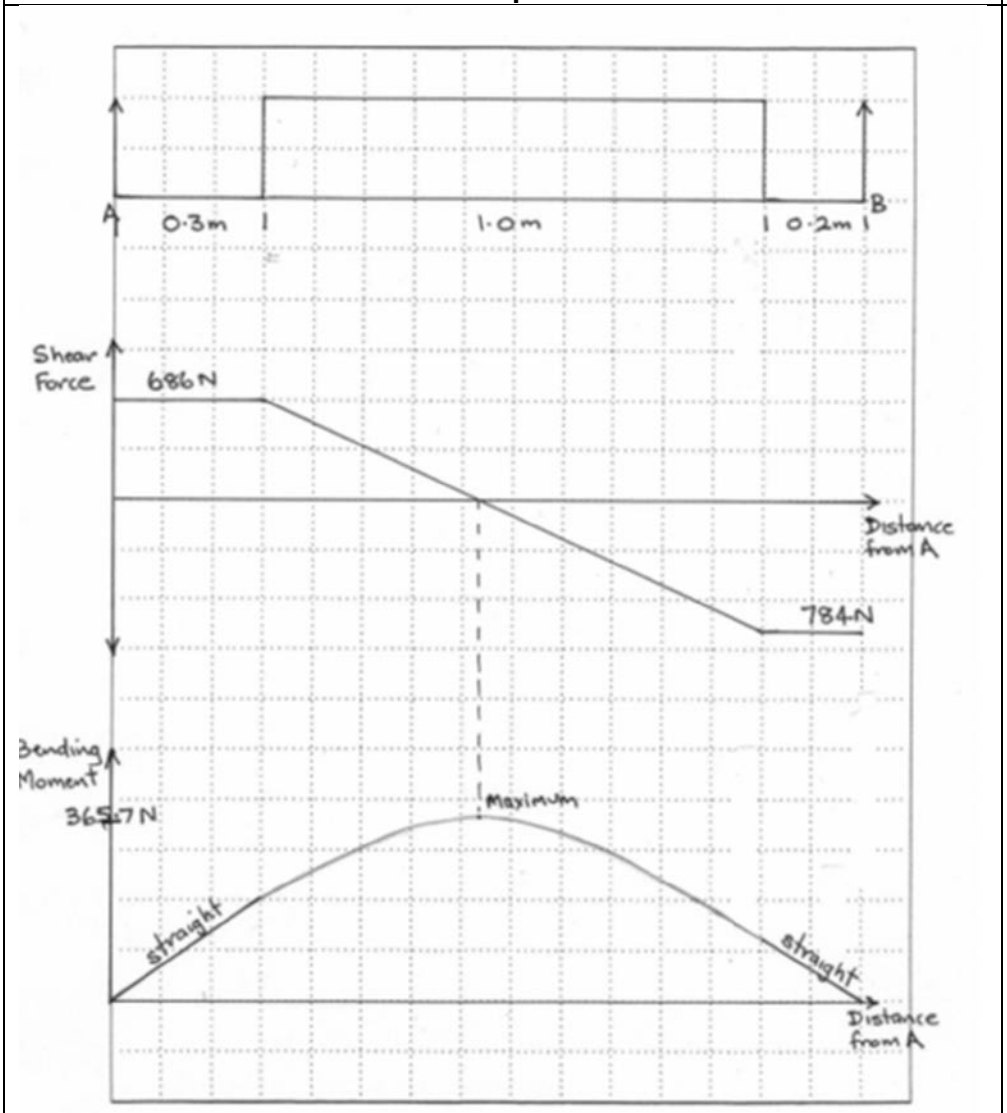
Description	Marks
Start at one end (usually the left of the beam)	1
Move along the beam, adding upward forces or subtracting downward forces	1–2
Total	**3**
Accept alternative answers as appropriate	

(ii) Calculate the bending moment at Point X, using the equation below. (3 marks)

$M = R_A \times L_{AX} - ½\ W\ (L_{AX} - L_{AP})^2$
where M = the bending moment
R_A = reaction force at A
L_{AX} = length of AX
W = force per metre in the loaded part of the beam
L_{AP} = length of AP

Description	Marks
Calculation of peak Bending moment (M) = (R_A) × (L_{AX}) – W /2($L_{AX} - L_{AP}$)^2 = 686 × 0.75 – 1470/2(0.75 – 0.3)^2	1–2
= 514.5 – 148.8 = 365.7 N m	1
Total	**3**

(d) Using the grid below and taking into account all relevant forces, construct a shear force diagram and a bending moment diagram for the beam. On the bending moment diagram indicate clearly the point of maximum bending moment. (9 marks)

Description	Marks
	
SF – correct overall shape	1
– labels and on correct ends of graph	1–2
– correct numeric labels on diagram	1–2
Bending moment Correct shape – straight lines each end	1–2
– curve	1
– peak matches shear force diagram	1
Total	**9**
Accept any other relevant working.	

Question 28 **(10 marks)**

(a) Using an appropriate formula from the Data book, show by calculation that the instantaneous velocity at the moment of impact with the ground is 7.668 m s^{-1}. (3 marks)

Description	Marks
$v^2 = u^2 + 2as$	1
$u = 0$	1
$v^2 = 2as = 2(–9.8)\ (–3)$ $v = 7.668$ m s^{-1}	1
Total	**3**

(b) Would the instantaneous velocity at the moment of impact change if the mass of the ball was increased to 250 g? Explain your answer, with reference to relevant equations. (4 marks)

Description	Marks
$E_k = E_p$	1
$½\ mv^2 = mgh$	1
$v^2 = 2gh$	1
$v = 7.668$ m s^{-1} Mass cancels out so, no change	1
Total	**4**
Accept calculation to obtain 7.668 (full marks)	

(c) After impact with the ground, the elastic ball rebounds to a height of 2.15 m. Calculate the percentage of the ball's initial energy that remains on rebound. (3 marks)

Description	Marks
2.15/3.0 × 100%	1–2
= 71.66%	1
Total	**3**

Question 29 **(19 marks)**

(a) The wheel nut can be just loosened when the brace is horizontal and a person of mass 75 kg stands on it at end A. Show that the length of the brace is 95.2 cm. Ignore the mass of the wheel brace in your calculation. (3 marks)

Description	Marks
Clockwise moment = anticlockwise moment	1
700 N m = 75 × 9.80 × L	1
L = 0.952 m	1
Total	**3**

(b) Using appropriate equations from your Data book, calculate the maximum deflection of the tip of the wheel brace as the nut starts to loosen when the 75 kg person stands on end A. Ignore the mass of the wheel brace in your calculation. (7 marks)

Description	Marks
$I_{xx} = \pi D^4/64$	1
$= \pi\ (0.025)^4/64$	1
$= 1.9175 \times 10^{-8}$	1
$Y = FL^3/3EI_{xx}$	1
$= 75 \times 9.80 \times 0.952^3 / (3 \times 2 \times 10^{11} \times 1.9175 \times 10^{-8})$	1–2
= 0.0551 m or 55.1 mm	1
Total	**7**
If E is used as 200 without conversion, max 6 marks.	

(c) A second wheel brace of the same length is a solid rod of rectangular section of height 3 cm and width 2 cm. Using appropriate equations from your Data book, calculate the maximum deflection of the tip of this wheel brace when the same 75 kg person stands on end A. Ignore the mass of the wheel brace in your calculation. (7 marks)

Description	Marks
$I_{xx} = bh^3/12$	1
$= 0.02 \times (0.03)^3/12$	1
$= 4.5 \times 10^{-8}$	1
$Y = FL^3/3EI_{xx}$	1
$= 75 \times 9.80 \times 0.952^3/(3 \times 2 \times 10^{11} \times 4.5 \times 10^{-8})$	1–2
= 0.0235 m or 23.5 mm	1
Total	**7**
If E is used as 200 without conversion max 6 marks.	

(d) If you did **not** ignore the mass of the wheel brace in part (c), would the new calculated deflection increase, decrease or stay the same? Give a reason for your answer. (2 marks)

Description	Marks
The deflection would increase because the weight of the brace contributes to the deflection.	1–2
Total	**2**
Accept any appropriate alternative answer.	

Question 30 **(14 marks)**

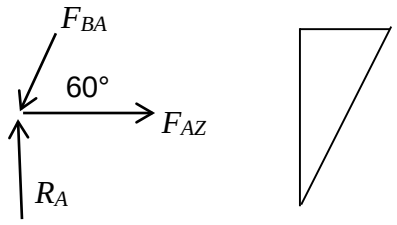
(a) Calculate the vertical reaction force at D. (5 marks)

Description	Marks
Moments about A Sum cm = Sum acm $R_D \times 10 = F_C \times 7.5 + F_{BC} \times 5$	1
$= (15 \times 10^3 \times 7.5 + 1.35 \times 10^3 \times 5 \times 5)/10$	1
$= (1.125 \times 10^5 + 3.375 \times 10^4)/10$	1–2
$= 14.6$ kN	1
Total	**5**

(b) Calculate the vertical reaction force at A. (4 marks)

Description	Marks
Sum of forces up = Sum of forces down	1
$R_A + R_D = 15 \times 10^3 + 1.35 \times 10^3 \times 5$	1
$R_A = 21.75 - R_D$ $= 21.75 - 14.6$	1
$= 7.15$ kN	1
Total	**4**

(c) (i) Calculate the force in the strut AB. (4 marks)

Description	Marks
	
$\sin 60° = R_A/F_{BA}$	1
$F_{BA} = R_A/\sin 60°$	1
$= 2.175 \times 10^4/\sin 60°$	1
$= 25.1$ kN	1
Total	**4**

(ii) Is AB under compression or under tension? Circle the answer below. (1 mark)

Description	Marks
Compression	1
Total	**1**

Question 31 **(16 marks)**

(a) Calculate the tension in the cable when the load is lifted initially from the back of the truck. (5 marks)

Description	Marks
Anticlockwise moments = clockwise moments	1
T sinθ × 1.7 = 760 × 9.8 × 1.5 + 60 × 9.8 × 1	1–2
= (111 72 + 588)/(1.70 × sin30.47°)	1
= 13.64 kN	1
Total	**5**

(b) Calculate the horizontal component of the reaction force that the beam exerts on the vertical support at X when the load is lifted initially from the back of the truck. (3 marks)

Description	Marks
$H = T$ × cosθ	1
= 13 640 cos30.47°	1
= 11.76 kN	1
Total	**3**

(c) Calculate the vertical component of the reaction force that the beam exerts on the vertical support at X when the load is lifted initially from the back of the truck. (5 marks)

Description	Marks
Sum forces up = sum forces down	1
Tsinθ + V = (760 +60) × 9.8	1–2
V = 820 × 9.8 – 13 640× sin30.47°	1
= 8036 – 6917 = 1.12 kN	1
Total	**5**

(d) What will happen to the vertical component of the reaction force at X as this occurs? Explain. (3 marks)

Description	Marks
Increase	1
As load approaches point X the tension in the cable decreases therefore	1
Tsinθ decreases. This results in $V = mg - T$sinθ increasing	1
Total	**3**
Accept any appropriate alternative answer.	

End of Section Two

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

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

32	B
33	C
34	A
35	D
36	A
37	A
38	B
39	A or B
40	C
41	D

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

Question 42 **(21 marks)**

(a) The speed of a DC electric motor can be controlled using the following methods. Explain the method of operation and give an advantage and disadvantage of each.

(i) Pulse width modulation (4 marks)

Description	Marks
PWM Voltage is switched on and off at varying rates to change the speed of a motor	1–2
Advantage: Very little power loss/infinitely variable	1
Disadvantage: not effective at low frequency	1
Total	**4**
Accept any appropriate alternative answer.	

(ii) Variable resistor (4 marks)

Description	Marks
Variable resistor A decrease in resistance will result in an increase in voltage	1–2
Advantage: Simple/inexpensive	1
Disadvantage: Incurs a power loss	1
Total	**4**
Accept any appropriate alternative answer.	

(iii) Increasing or decreasing the number of cells in the power supply battery. (4 marks)

Description	Marks
Changing no. of cells in a power supply Adding or remove cells in series	1–2
Advantage: Simple/unlikely to fail/delivers more current or power	1
Disadvantage: limited to fixed voltage steps/physical factors such as space for extra cells	1
Total	**4**
Accept any appropriate alternative answer.	

(b) A windscreen wiper motor and incorporated gearbox are used to rotate a spit on a homemade barbecue. The required rotation rate of the spit is 1.6 rpm.

(i) Calculate the motor rpm given that the drive pulley has a rotational speed of 44 rpm and the gearbox ratio is 50:1. (1 mark)

Description	Marks
Motor rpm = 44 × 50 = 2200 rpm	1
Total	**1**

(ii) Calculate the diameter of the spit pulley required to keep the spit rotating at 1.6 rpm if the motor speed is reduced to 1600 rpm. (4 marks)

Description	Marks
Motor speed = 1600/50 = 32 rpm	1
Pulley ratio = 32/1.6 = 20	1
Spit pulley = Drive pulley × 20 = 220 × 20	1
=4 400 mm or 4.4 m	1
Total	**4**

(iii) Determine the degrees/step for the stepper motor if the stepper motor is stepped 40 times to achieve one rotation. (1 mark)

Description	Marks
Degrees /step = 360/40 = 9 degrees/step	1
Total	**1**

(iv) How many steps should occur in one minute to ensure that the spit still rotates at 1.6 rpm? (3 marks)

Description	Marks
Ratio drive pulley to spit pulley = 20/220 = 1:10	1
Steps per minute = 0.1 × 1.6 × 40	1
= 6.4 steps	1
Total	**3**

Question 43 **(17 marks)**

(a) Complete the following table of component functions. (7 marks)

Description		Marks
Light dependent resistor (LDR)	Changes resistance when light intensity changes	1
Fuse	Breaks a circuit when a current level is exceeded	1
Transistor (NPN)	Acts as a switch (or an amplifier)	1
Thermistor (NTC)	Change resistance in an inverse relationship to temperature	1
Servo	Able to control precise movements of a rotary shaft	1
Rectifier diode	Allows current to flow in one direction only	1
Polarised capacitor	Stores charge	1
	Total	**7**
Accept any appropriate alternative answer.		

(b) Complete the following table of resistor and capacitor values and units. (2 marks)

Description		Marks
4 700 000 or 4.7×10^6	Ω	1
or 4.7	M Ω	
22 000	pF	1
or 22	nF	
or 0.022	µF	
	Total	**2**
Both parts of each answer must be correct to gain the mark		

(c) (i) Complete the table below for a 68 Ω, 5% tolerance, 1 W resistor. (2 marks)

blue	grey	black	gold

Description	Marks
All value colours correct	1
Tolerance colour correct	1
Total	**2**

(ii) Determine the maximum and minimum values this resistor can have. (1 mark)

Description	Marks
Minimum 64.6 Ω maximum 71.4 Ω	1
Total	**1**
Both answers must be correct to gain the mark	

(d) What would be the label on a 150 pF polyester capacitor? (1 mark)

Description	Marks
151	1
Total	**1**

(e) Complete the following table for each component. (4 marks)

Description			Marks
Component 1	V = 0.072 66V	or 72.66 mV	1
	I = 0.060 55 A	or 60.55 mA	1
Component 2	I = 45.45 A		1
	R = 9.68 Ω		1
		p	**4**

Question 44 **(14 marks)**

(a) Calculate the voltage applied to pin four of the microcontroller when the float switch is closed. (3 marks)

Description	Marks
V out = $R2/(R1+R2) \times 5$	1
= 10 000/(10 000 + 100 000) × 5	1
= 0.454 5 V	1
Total	**3**

(b) Calculate the minimum and maximum current that could be supplied to pin three of the microcontroller. (3 marks)

Description	Marks
$V_{min} = IR$ $I = V/R$	1
I = 12/17 000 = 0.000 705 A or 0.705 mA	1
$V_{max} = IR$ $I = V/R$ I = 12/12000 = 0.001 A or 1 mA	1
Total	**3**
Candidates who state that the current supplied to the input pin of a microprocessor is always zero gain three marks.	

(c) The circuit has two LEDs. Explain the purpose of each. (2 marks)

Description	Marks
LED 1 indicates that the power supply is on	1
LED 2 indicates that power is being supplied to the output	1
Total	**2**
Accept any appropriate alternative answer.	

(d) Why does each LED have a different value resistor in series with it? (1 mark)

Description	Marks
Each LED has a different value resistor because the each has a different voltage power supply. The higher voltage requires a larger resistance.	1
Total	**1**
Accept any appropriate alternative answer.	

(e) An ideal multimeter is connected across the pins of the voltage regulator. State the reading that you would see across (3 marks)

A to B
B to C
A to C

Description	Marks
Voltage A to B = 12 V	1
Voltage B to C = 5 V or –5 V	1
Voltage A to C = 7 V	1
Total	**3**

(f) Calculate the base current of the transistor, given th the collector current is 400 mA and the h_{FE} is 300. (2 marks)

Description	Marks
$h_{FE} = \frac{I_{collector}}{I_{base}}$ Base current = $\frac{\text{collector current}}{h_{FE}}$	1
Base current = $\frac{\left(400 \times 10^{-3}\right)}{300}$ Base current = 0.001 33 A or 1.33 mA	1
Total	**2**

Question 45 **(16 marks)**

(a) Calculate the resistance between A and C in the circuit above. (3 marks)

Description	Marks
$1/R_T = 1/R_1 + 1/R_2$	1
$1/R_T = 1/(270 + 330) + 1/(180 + 220)$	1
$R_T = 240\ \Omega$	1
Total	**3**

(b) Calculate the total resistance of the circuit. (2 marks)

Description	Marks
$R_T = R_1 + R_2$ $R_T = 240 + 120$	1
$R_T = 360\ \Omega$	1
Total	**2**

(c) Find the current at E (the total current in the circuit). (2 marks)

Description	Marks
$V = IR$ $I = V/R = 9/360$	1
$I = 0.025$ A or 25 mA	1
Total	**2**

(d) Find the current through the 270 Ω resistor. (2 marks)

Description	Marks
$I_{270} = I_{ABC} = 0.4 \times I_{TOTAL}$ $= 0.4 \times 0.025$	1
$= 0.001$ A or 10 mA	1
Total	**2**

(e) Find the current through the 220 Ω resistor. (2 marks)

Description	Marks
$I_{220} = I_{ADC} = 0.6 \times I_{TOTAL}$ $= 0.6 \times 0.025$	1
$= 0.0015$ A or 15 mA	1
Total	**2**

(f) Find the power dissipated in the 330 Ω resistor. (2 marks)

Description	Marks
$P = I^2R$ $= 0.01^2 \times 330$	1
$= 0.033$ W or 33 mW	1
Total	**2**

(g) Find the potential difference between B and D (V_{BD}). (3 marks)

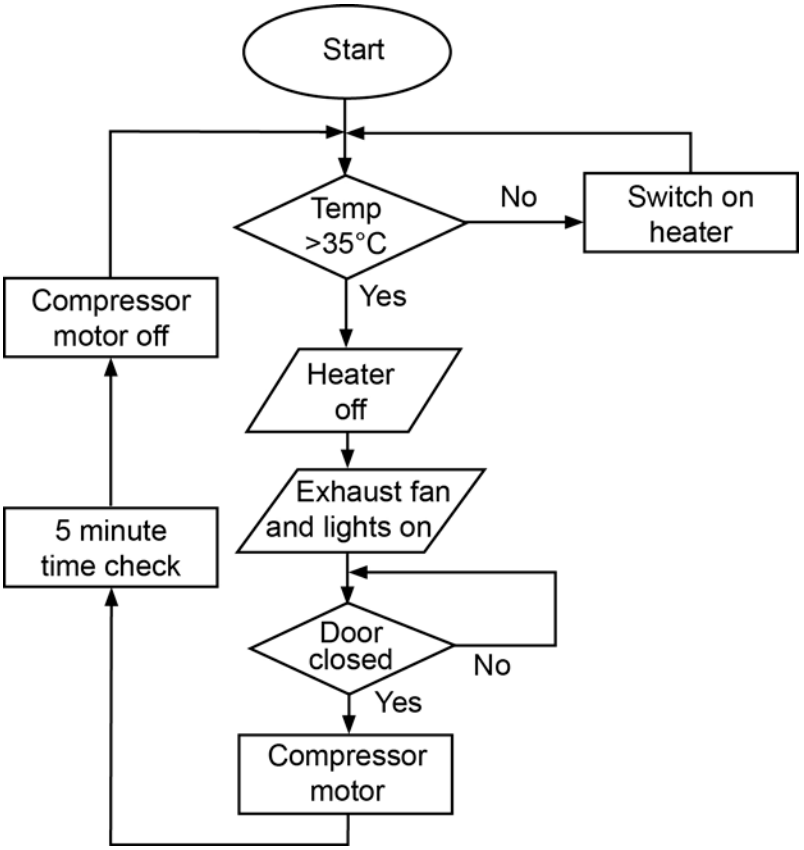
Description	Marks
$V_{270} = I_{ABC} \times 270$ $= 0.01 \times 270$ $= 2.70$ V	1
$V_{180} = I_{ADC} \times 180$ $= 0.015 \times 180$ $= 2.70$ V	1
Therefore $V_{BD} = 0$ V	1
Total	**3**

Question 46 **(13 marks)**

(a) Using the standard flowchart symbols shown in the Data book, complete the flowchart below for this spray-painting booth. (9 marks)

All relevant feedback loops for this operation must be shown.

Description	Marks
Correct use of start, decision and output/process symbols	1
Flow chart will not allow compressor to turn on unless temperature is above 35 °C	1
Flow chart will not allow compressor to turn on unless exhaust ventilation and lights are on	1
Flowchart will not allow compressor to turn on unless door is closed	1
System rechecks every 5 minutes	1
Flow chart will not allow compressor to turn on unless all three parameters are correct (1 mark for each)	1–3
Checks every 5 minutes	1
Total	**9**
Accept any appropriate alternative answer.	



(b) Due to occupational safety and health requirements the negative feedback loop below must be added to increase the safety features of this booth.

(i) How does this safety system operate? (2 marks)

Description	Marks
Recognises that the vapour concentration is too high for human safety.	1
Stops the spray gun/shuts down the booth.	1
Total	**2**
Accept any appropriate alternative answer.	

(ii) State **two** other components of the booth that could be controlled by this feedback loop to further improve safety. (2 marks)

Description	Marks
States two other components, one mark each	1–-2
Appropriate examples include: • Vary the temperature more accurately • Increase the speed of the exhaust fan • Open the door	
Total	**2**
Accept any appropriate alternative answer.	

Question 47 **(19 marks)**

(a) Calculate the voltage across the 120 kΩ resistor when the relay is activated. (2 marks)

Description	Marks
Use Kirchhoff's second law V across 120 kΩ resistor = (9 - 0.7) V	1
= 8.3 V	1
Total	**2**

or

Description	Marks
V = (120 000/130 500) × 9	1
= 8.28 V	1
Total	**2**

(b) Calculate the power dissipated in the 120 kΩ resistor when the relay is activated.

(2 marks)

Description	Marks
$P = V^2/R$	1
$= 8.3^2/120\ 000$ = 0.574 mW	1
Total	**2**

(c) Determine the current required to operate the relay. (2 marks)

Description	Marks
$I = V/R$ = 5/100	1
= 0.05 A or 50 mA	1
Total	**2**

(d) Calculate the required value for resistor $R1$. (3 marks)

Description	Marks
V_{R1} = 4.00 V	1
I_{R1} = 0.05 A	1
$R_1 = V/I$ = 4.00/0.05 = 80 Ω	1
Total	**3**

Accept alternative calculation method e.g. using Kirchhoff's law.

(e) (i) Calculate the time taken to raise the door to a height of 3 m, given that the pinion gear has a radius of 3 cm. (5 marks)

Description	Marks
Circumference = $2\pi r$ = 2 × 3.14 × 0.03 = 0.188 m	1
3000 rpm = 50 rps 40:1	1
reduces to 1.25 rps	1
1.25 × 0.188 = 0.235 m s^{-1}	1
$t = s/v$ t = 3/0.235 t = 12.765 s	1
Total	**5**

(ii) Calculate the power required to raise the door in this time. (2 marks)

Description	Marks
$P = mgh/t$	1
= (140 × 9.8 × 3)/12.765 = 322.44 W	1
Total	**2**

(f) Given that the motor is 80% efficient, calculate the current drawn by the motor while lifting the door. (3 marks)

Description	Marks
$P \div 0.8 = V \times I$	1
$322.44 \div 0.8 \times = 240 \times I$ $I = \dfrac{322.44}{0.8 \times 240}$	1
$I = 1.679\ 4$ A	1
Total	**3**

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