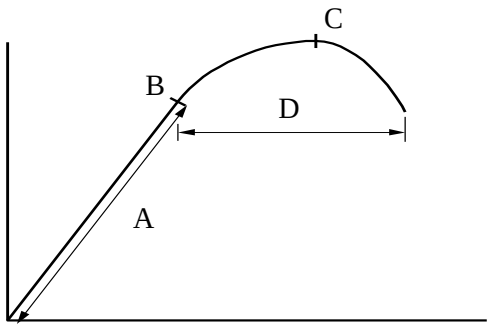
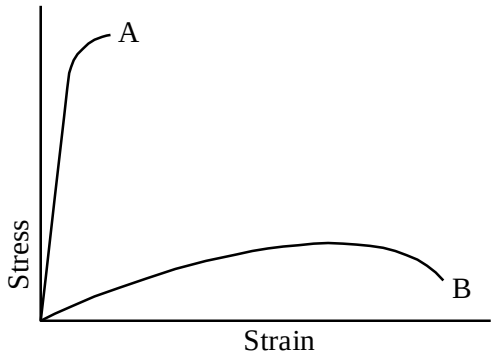
Question			Mark Allocation		Marks	
11	**a**		Holds position/precision/quick stop – start	any 2@1		**2**
	b		crowdspot: gosub adcread		1	
			if data > 182 then movespot		2	
			return	(mark allocated below)		
				calc.no of step loops (144/1·8)/4 = 80/4 = 20	2	
				calc. pause 4000/80 = 50ms	1	
			movespot: for b1 = 1 to 20	incl.*next b1* below	1	
			(let) pins = %1010 0000			
			pause 50			
			(let) pins = %1001 0000			
			pause 50			
			(let) pins = %0101 0000			
			pause 50	correct step sequence	1	
			(let) pins = %0110 0000	all 4 pauses	1	
			pause 50			
			next b1			
			pause 1500		1	
				calc. pause 1600/80 = 20	1	
			for b1 = 1 to 20	incl.*next b1* below	1	
			(let) pins = %0110 0000			
			pause 20			
			(let) pins = %0101 0000			
			pause 20			
			(let) pins = %1001 0000			
			pause 20			
			(let) pins = %1010 0000	correct step sequence	1	
			pause 20	all 4 pauses	1	
			next b1			
			return	both returns	1	**15**
	c	**i**	E = 196kN/mm^2	from data book	1	
			UTS = 430 N/mm^2	from data book	1	
			$\sigma = 430/10 = 43$N/mm^2	answer	1	
			$\varepsilon = \sigma/E = 43/196 \times 10^3$	all substitutions	1	
			$= 0{\cdot}219 \times 10^{-3}$	answer	1	
			$\Delta 1 = \varepsilon \times 1 = 0{\cdot}219 \times 10^{-3} \times 120$	all substitutions	1	
			$= 0{\cdot}026$mm	answer & units	1	**7**
		ii	Force on each bolt = 330/2 = 165 + 50	answer (165)	1	
			=215N	answer	1	
			$A = F/\sigma = 215/43$	both substitutions	1	
			$= 5{\cdot}00$mm^2	answer	1	
			$d = \sqrt{4A/\pi} = \sqrt{4 \times 5{\cdot}00/3{\cdot}14}$	transposition	1	
			$= 2{\cdot}52$mm	answer including units	1	**6**

Question			*Mark Allocation*			*Marks*	
1	**a**	**i**	feedspeed:	if pin 1 = 1 then finefeed		2	
				if pin 2 = 1 then draftfeed		2	
				return			
			finefeed:	gosub fine		1	
				return			
			draftfeed:	gosub draft		1	
				return	1 for all 3 returns	1	**7**
		ii	draft:	for b0 = 1 to 255		1	
				high 7			
				pause 10			
				low 7	1 high & low 7	1	
				pause 2	1 both pauses	1	
				next b0		1	
				return	1 including label	1	**5**
	b		time for each counter loop = 3060/255		both substitutions	1	
				= 12ms	answer	1	
				ratio 3:9			
				mark 3ms		1	
				space 9ms		1	**4**
							(16)

Question		Mark Allocation	Marks	
3.	**(a)**	Close: TIME = 10	1	
		for b0 = 1 to 20 (or COUNTER) Including 'next b0' below	1	
		for b1=1 to 10	1	
		high 4		
		pause 10 > both for 1 mark	1	
		low 4	1	
		pause TIME	1	
		next b1	1	
		TIME = TIME + 2	1	
		if pin2 = 1 then finish	2	
		next b0		
		finish: return including label 'close' above	1	**11**
	(b)	(i) Pulse Width Modulation (PWM)	1	**1**
		(ii) Valve closes at a reducing speed either	1	
		until closed or a fixed time has elapsed.	1	**2**
	(c)	Mark = 10 ms		
		Max Space $= 10 + (2 \times 20) = 50$ ms		
		Mark: Space ratio = 1:5	2	**2**
				(16)
4.	**(a)**	(i) Darlington Pair/Driver	1	**1**
		(ii) Protection diode to prevent current generated at switch-off damaging transistor.	2	**2**
	(b)	$V_{be2} = 0.7\,V$ by inspection	1	
		$V_{3600} = 2.3 - 1.4 = 0.9\,V$ calculation	1	
		$I_{b1} = \frac{V}{R} = \frac{0.9}{3600}$ all substitutions	1	
		$I_{b1} = 0.25\,mA$ answer	1	
		$I_{b2} = 2.5 \times 10^{-6} \times 80$ substitutions	1	
		$= 0.02\,A$ answer	1	
		Pump resistance $R_P = \frac{P}{I^2}$		
		$= \frac{500}{2.13^2}$ substitutions	1	
		$= 110\,\Omega$ answer	1	
		$h_{FE2} = \frac{I_c}{I_b} = \frac{2 \cdot 13}{0 \cdot 02}$ substitutions	1	
		$= 106.5$ answer	1	
		Overall current gain = $h_{FE1} \times h_{FE2}$		
		$= 80 \times 106 \cdot 5$ substitutions	1	
		$= 8520$ answer	1	**12**
		See Supplementary Sheet, page 6		**(15)**

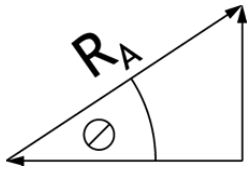
Question		Mark Allocation	Marks	
2.	**(a)**	$A = 100\ mm^2$ answer	1	
		$\sigma = \frac{F}{A}$		
		$= \frac{1000}{100} \quad \frac{2000}{100} \quad \frac{3000}{100} \quad \frac{4000}{100} \quad \frac{5000}{100}$		
		$= 10\ N/mm^2 \quad 20\ N/mm^2 \quad 30\ N/mm^2 \quad 40\ N/mm^2 \quad 50\ N/mm^2$		
		any of the above (units not necessary)	1	
		$\varepsilon = \frac{\Delta l}{l}$		
		$= \frac{0{\cdot}02}{200} \quad \frac{0{\cdot}04}{200} \quad \frac{0{\cdot}06}{200} \quad \frac{0{\cdot}08}{200} \quad \frac{0{\cdot}10}{200}$		
		$= 1 \times 10^{-4} \quad 2 \times 10^{-4} \quad 3 \times 10^{-4} \quad 4 \times 10^{-4} \quad 5 \times 10^{-4}$		
		any of the above	1	
		$E = \frac{\sigma}{\varepsilon} \qquad \frac{20}{2 \times 10^{-4}}$ (must be two matching substitutions)	1	
		$E = 100\ kN/mm^2$ answer and unit	1	**5**
	(b)	Soft Brass		**1**
	(c)			
		A – elastic range	1	
		B – yield point	1	
		C – ultimate load	1	
		D – plastic range	1	
				4
	(d)			
		Brittle trace	1	
		Ductile trace	1	
		Correct labels	1	
		Correct axis	1	
				4
				(14)

Part Two: Marking Instructions for each Question

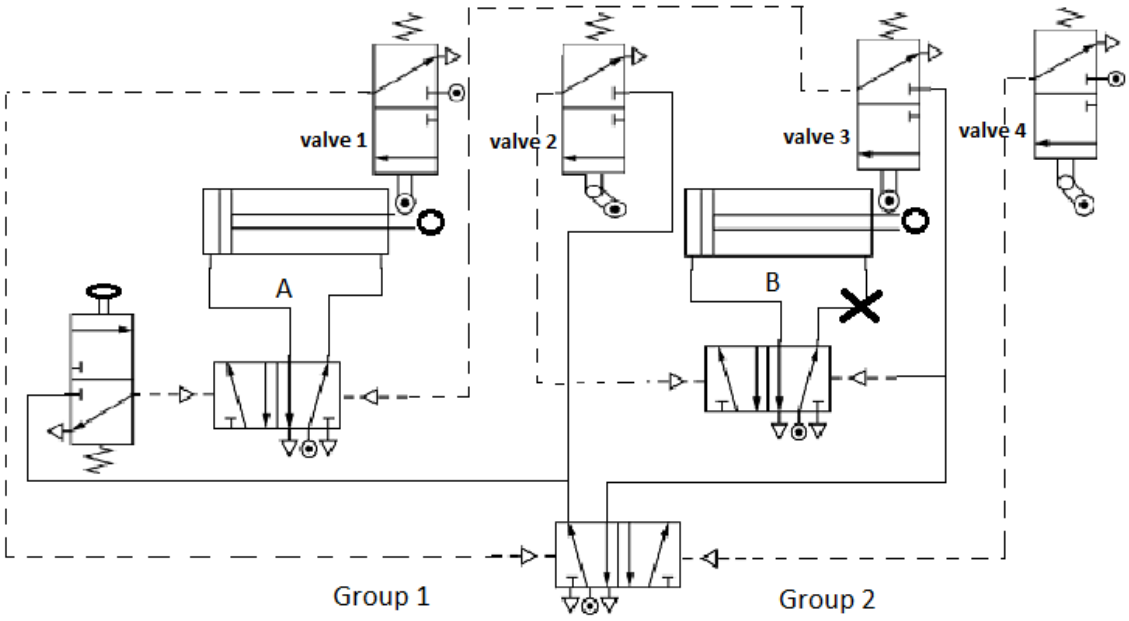
SECTION A

Question			Expected Answer/s	Max Mark	Additional Guidance
1	**a**	**i**	ALU – Arithmetic Logic Unit **(1 mark)** EEPROM – Electronic Erasable Programmable Read Only Memory **(1 mark)**	**2**	Full and correct name
1	**a**	**ii**	EEPROM - Stores program **(1 mark)** RAM - working memory / stores temporary programs data **(1 mark)**	**2**	Functional related statement not characteristics
1	**b**	**i**	let dirs.=% 11011000	**1**	
1	**b**	**ii**	Binary number	**1**	
2	**a**	**i**	$E_h = Cm\Delta t$ (26°-22° = 4°C) **(1 mark)** $= 4190 \times 1200 \times 4$ **(1 mark)** = 20112000J (20.1MJ) **(1 mark)**	**3**	
2	**a**	**ii**	$E_{in} = \frac{E_{out}}{\text{Efficiency}}$ $= \frac{20112000}{0 \cdot 82}$ **(1 mark)** = 24526829·27J (24.5MJ) **(1 mark)**	**2**	Allow FTE (a)(i)
2	**a**	**iii**	$I = \frac{Ee}{tv}$ $= \frac{24526829 \cdot 27}{3600 \times 230}$ **(1 mark)** = 29·62A **(1 mark)**	**2**	Allow FTE (a)(ii)
2	**b**		Reduce heat loss (Insulate walls, cover when not in use, smaller water surface area – must include location) – 1 Use a more efficient motor/pump – 1 Use/improve bearings, material (slipper), lubricate etc) – 1 Clean filter (reducing resistance to water flow)	**2**	Any appropriate descriptive response

Question			Expected Answer/s	Max Mark	Additional Guidance
11	**a**	**i**	$E_e = Pt$ $\quad t = 3 \times 60$ $= 180$ secs $= 42000 \times 180$ **1 mark** $= 7560$kJ **1 mark**	**2**	
		ii	$E_p = mgh$ $= 1000 \times 9 \cdot 81 \times 500$ **1 mark** $= 4905$kJ **1 mark**	**2**	
		iii	$\eta = \frac{E_{out}}{E_{in}}$ $= \frac{4905000}{7560000}$ **1 mark** $= 0 \cdot 648$ or $= 65\%$ **1 mark**	**2**	Allow FTE from (a) (i) and/or (ii)
	b	**i**	friction at moving parts	**1**	Not type of energy lost
		ii	Lubricate gears, bearings or 'slipper' materials used	**1**	

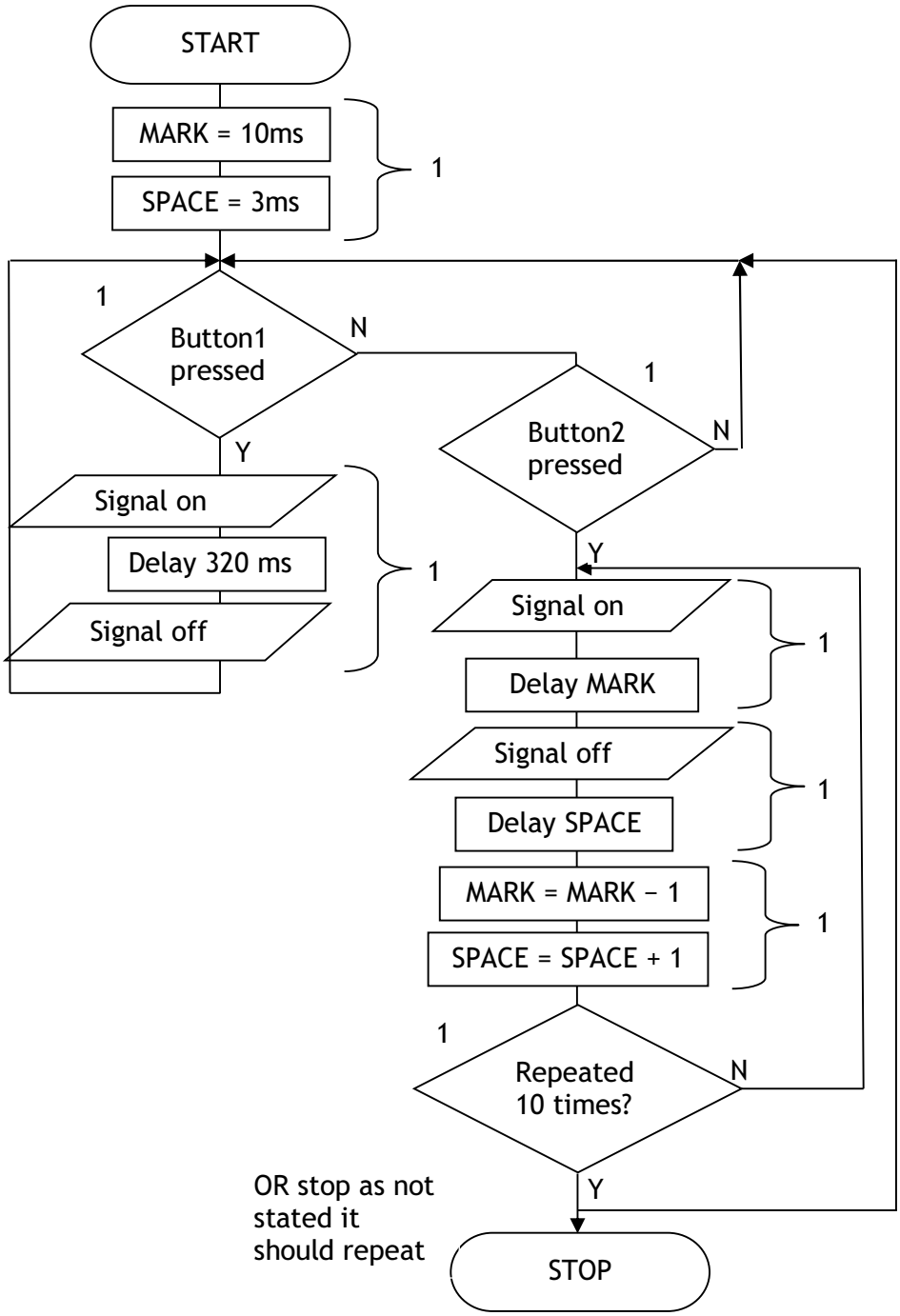
Question			Expected response	Max mark	Additional guidance
			• contractor vehicles may cause damage to roads, creating repair bills for local council		
6	**d**		UDL: 2000 × 1·3 = 2600 N at 0·65 m (midpoint) moments about B: (3000 × sin63 x 0·3) + (2600 × 0·65) = V_A × 1·3 $\Rightarrow V_A$ = 1917 N H_A = 3000 × cos63 = 1362 N $R_A = \sqrt{(1362^2 + 1917^2)}$ = 2351 N tanθ = 1917/1362 $\Rightarrow$ θ = 55˚ 	**4**	1 mark for UDL (2600 at 0·65) 1 mark for V_A 1 mark for R_A 1 mark for angle
7	**a**		Possible responses could include: Electrical/electronic engineer: programming (skill), understanding of components (knowledge). Mechanical engineer: design of lock mechanism (skill), knowledge of properties of materials.	**4**	1 mark for each reasonable skill or knowledge — must be relevant to the type of engineer (do not accept generic skills, such as analysis, design …), and must be relevant to the context.
7	**b**		Any reasonable suggestion, with reason given; eg plastic would be lighter and could be manufactured cheaply.	**1**	Mark given for a relevant reason — no mark for naming a material only.
7	**c**	**i**	$\bar{B}$ = O·S + L	**1**	

Question			Expected Answer(s)	Max Mark	Additional Guidance
10.	(a)		As cylinder B has to out-stroke and then in-stroke while cylinder A remains out-stroked the air to valve 2 and valve 3 must be controlled **(1)** to prevent them both signalling cylinder Bs 5/2 valve at the same time.**(1)** Or when B out-strokes Its 5/2 valve will have both pilots active **(1)** so cylinder B will be locked in its present state **(1)**	**2**	This will be worded in many ways 2 marks are awarded for an understanding of the need for group air. and 1 mark for some understanding not deserving of 2 marks.



Question			Expected Answer(s)	Max Mark	Additional Guidance
	(b)		When the technician presses the button Group 1 air Sends a pilot signal **(1)** to make Cylinder A outstroke **(1)** Valve 2 then sends a pilot signal to make Cylinder B outstroke **(1)** Roller trip valve 4 then changes the supply to group 2 air **(1)** This sends a pilot signal to make Cylinder B in-stroke again **(1)** Then valve 3 makes Cylinder A in-stroke **(1)** Valve 1 returns the supply to Group 1 air **(1)**	**7**	The language will vary as may the order of description. If in your view it conveys understanding of the function then give the mark.
	(c)		In the exhaust line for B outstroke (x) **(1)** Because the speed will be reduced by restricting the cylinder exhaust out flow **(1)** Without compromising the force exerted or the smoothness and lack of jerkiness of the stroke **(1)**	**3**	

Question	Expected Answer(s)	Max Mark	Additional Guidance
(d)	See flowchart below	8	Marks given for decision boxes include the associated lines. Yes, No labels if missing can be interpreted from the line. The first instance of using the wrong flowchart syntax should lose the mark subsequent occasions should gain the mark if the information is correct. Writing code or an algorithm is wrong technology at higher – zero marks



[END OF MARKING INSTRUCTIONS]

Section A

Question		*Mark Allocation*	*Marks*	
1.	**(a)**			

A	B	C	Z
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

3 marks for all z output
2 marks 7 or 6 z correct
1 mark 5 or 4 z correct — 1
0 marks 3 or less correct

1

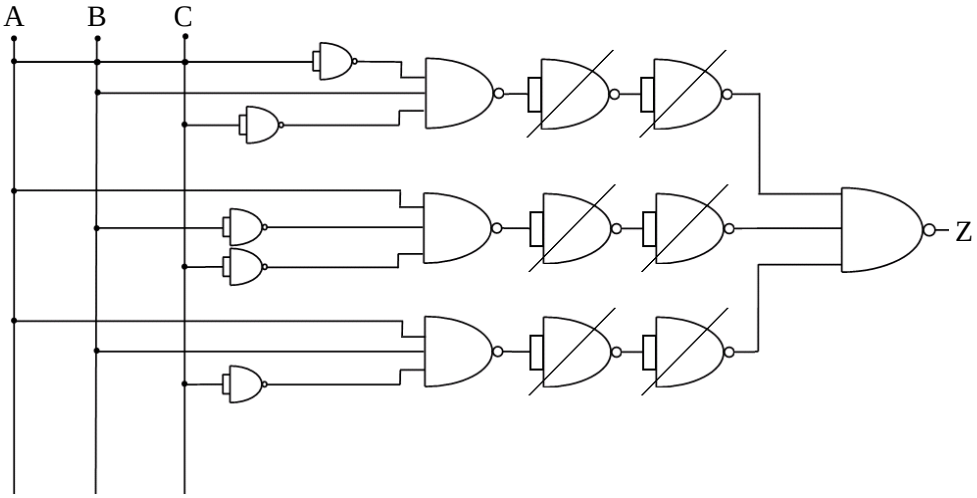
1 — **3**

(b) $Z = \overline{A}.B.\overline{C} + A.\overline{B}.\overline{C} + A.B.\overline{C}$

1 mark for each correct combination — 3
1 mark for logic operators — 1 — **4**

Alternatively $Z = (A + B).\overline{C}$ (if operators swapped, deduct 1 mark)
(C not $\overline{C}$, deduct 1 mark)
(missing brackets, deduct 1 mark)

(c)

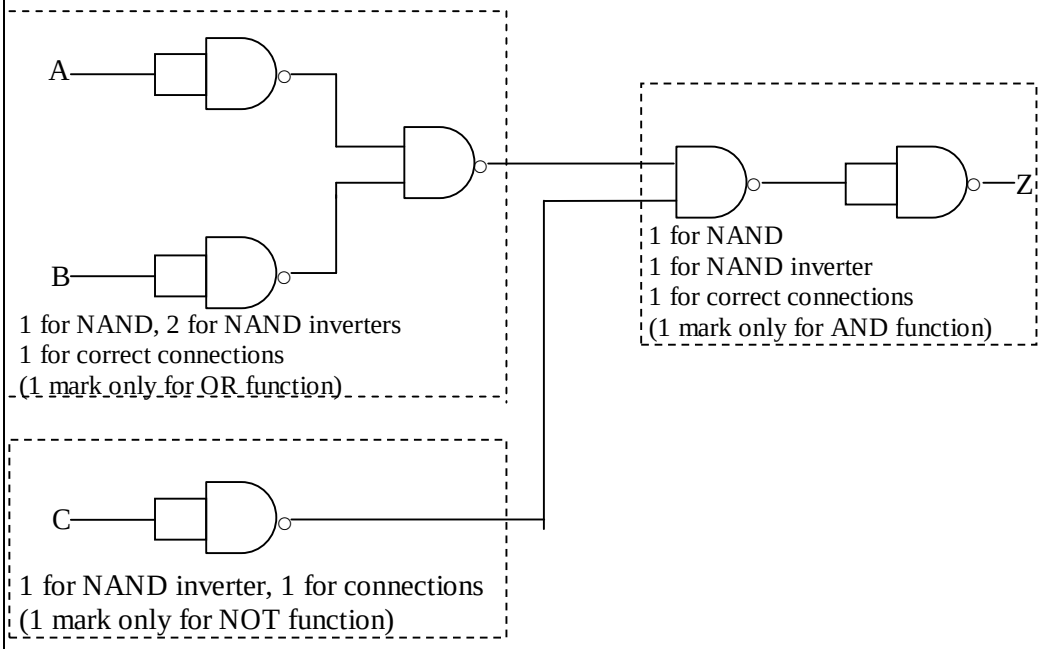


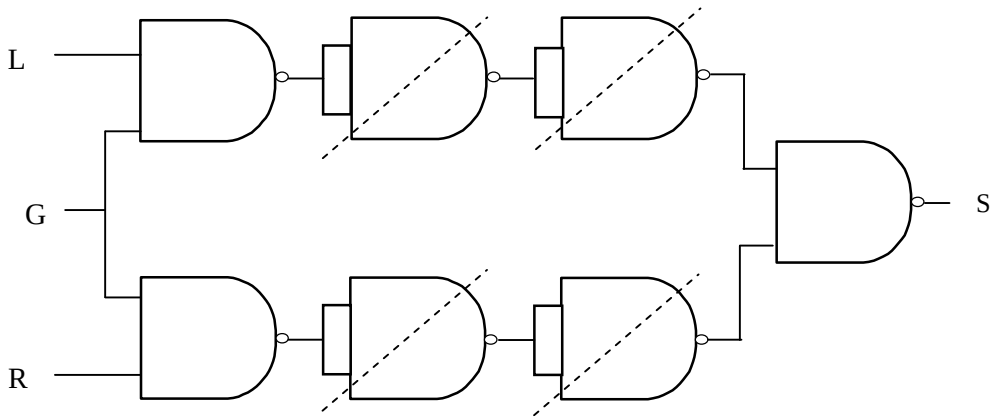
AND gate equivalents and connections — 3
NOT gate equivalents and connections — 3
OR gate equivalent and connections — 2
Cancellation of redundant gates — 1 — **9**

(16)

See Supplementary Sheet for part (c) from simplified Boolean (page 3)

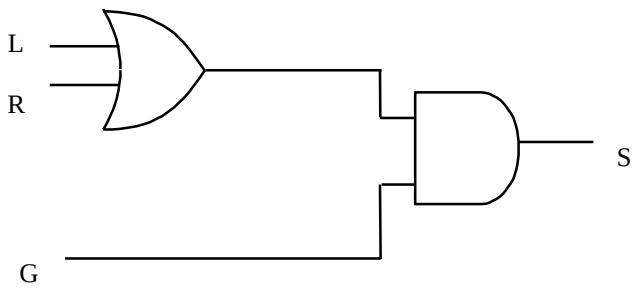
Supplementary Sheet

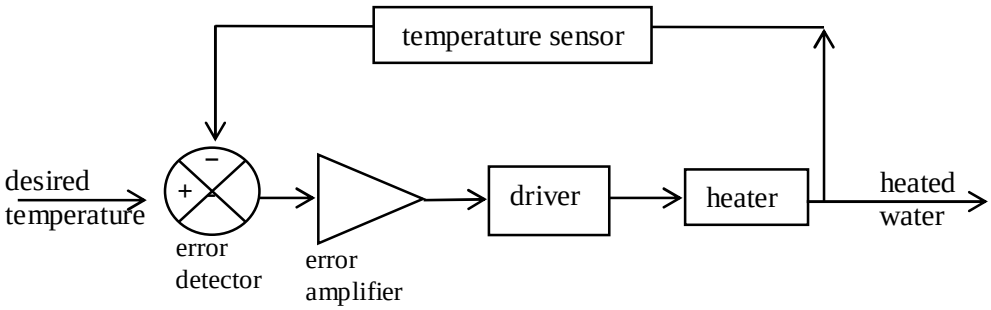
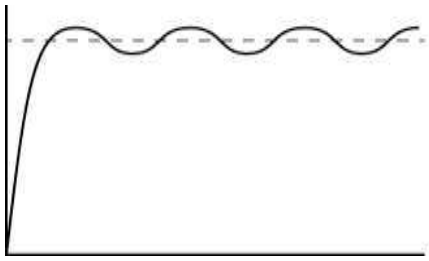
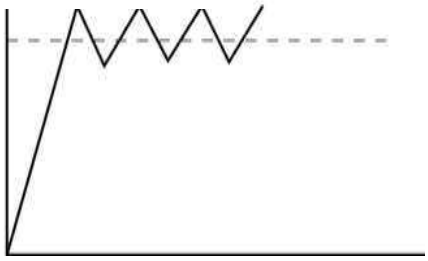
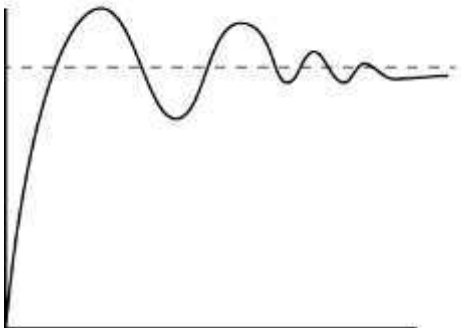
Question		*Mark Allocation*	*Marks*	
1.				
	(b)	$Z = (A+B) \bullet \overline{C}$ (simplified form)		
	(c)			

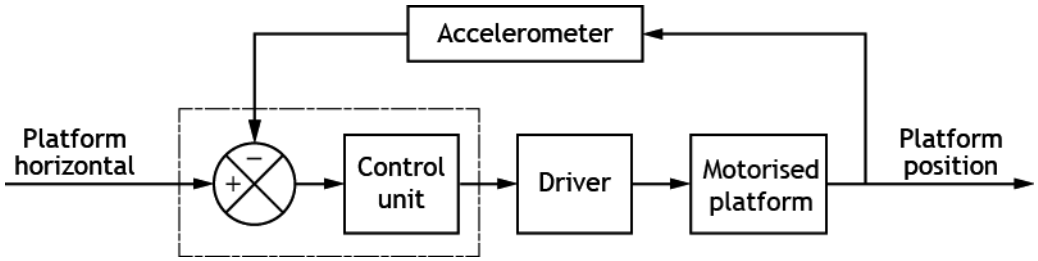
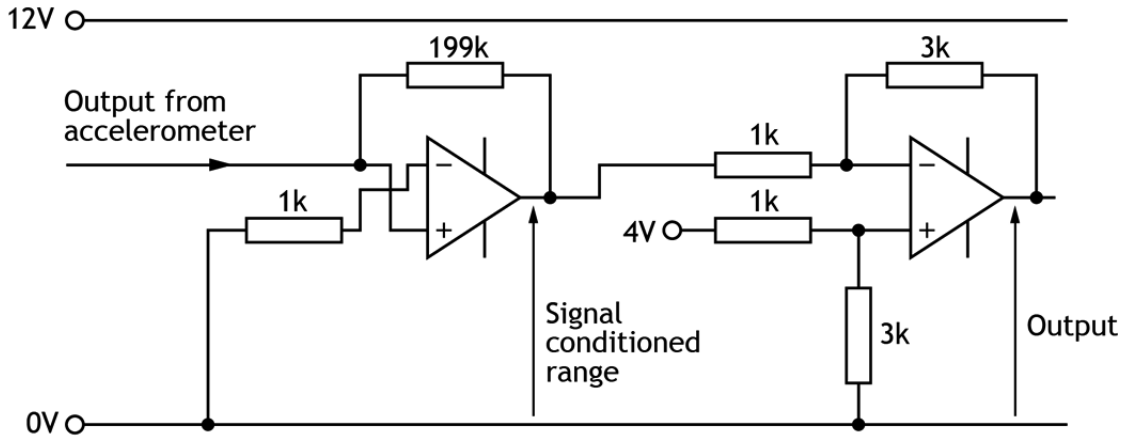
Question		*Mark Allocation*		*Marks*	
1.	**a**	S = (L.G) + (R.G) (brackets not necessary) S = ($\bar{L}$.G.R) + (L.G.$\bar{R}$) + (L.G.R) S = (L + R) . G	AND functions 1 each OR function 1 Each statement 1 L+R 1 .G 1 ( ) 1	3	**3**
	b		Two AND equivalents @ 1 each OR equivalent deleting redundant gates	2 1 1	**4**
	c				**5**

L	G	R	M	N	P	Q	S
0	0	0	1	1	0	1	0
0	0	1	1	0	1	1	0
0	1	0	1	1	0	1	0
0	1	1	1	0	1	0	1
1	0	0	0	1	1	1	0
1	0	1	0	0	1	1	0
1	1	0	0	1	1	0	1
1	1	1	0	0	1	0	1

1 each fully correct column for M,N,P,Q and S

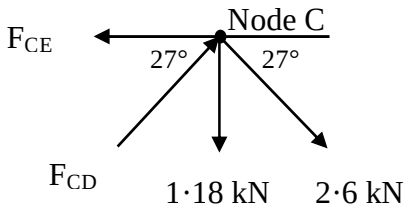
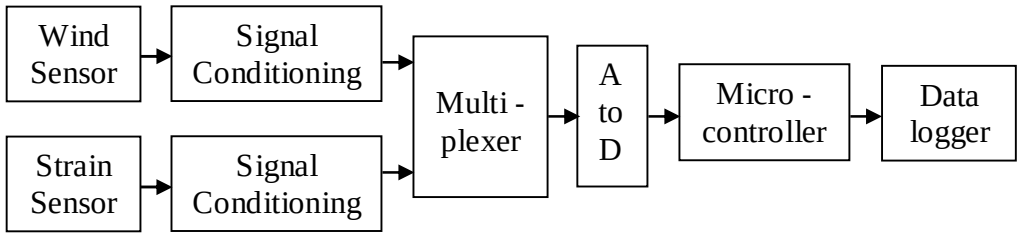
d		correct OR correct AND correct interconnections	1 1 1	**3**
				(15)

Question			Mark Allocation	Marks	
5	**a**	**i**			
			desired position signal & correct connection to error detector	1	
			error detector & error amplifier	2	
			driver	1	
			heater and output	1	
			temp. sensor and correct feedback loop	1	**6**
		ii	Comparator	1	**1**
	b	**i**	TEMPERATURE (°C)  TIME **OR** TEMPERATURE (°C)  TIME		
			Two correct axes	1	
			"Desired Temp" line	1	
			1st over shoot around desired temp	1	
			Cycle repeats a few times	1	**4**
	c	**i**	Difference Amplifier	1	**1**
		ii			
			Error reducing	1	
			Steady Output	1	**2**
					(14)

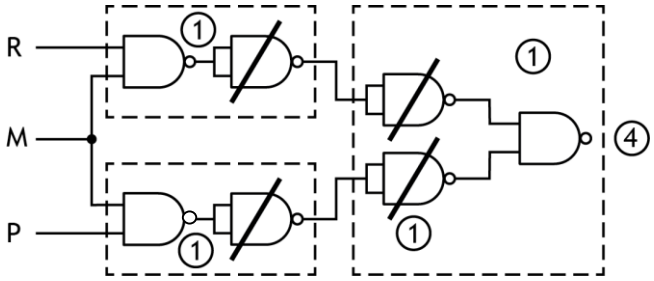
Question			Expected response	Max mark	Additional guidance
9	a			6	1 mark for labelling driver and motorised platform 1 mark for labelling control unit 1 mark for labelling input and output, and adding all connecting arrows 1 mark for completing the feedback loop 1 mark for accelerometer 1 mark for details of error detector
9	b		 Non-inverting op-amp gain = 2/0·01 = 200 (1 mark) 200 = 1 + R_F/R_1 => R_F/R_1 = 199 (so, any values in this ratio) (1 mark) Difference amp gain = R_F/R_1 = 3 (so, any values in this ratio) (1 mark)	6	3 marks for working (as shown) 2 marks for completing diagram (as shown) 1 mark for showing all resistor values on diagram

Question		Mark Allocation		Marks	
7	**(a)**	Comparator			**1**
	(b)	(i) Resistance of thermistor at 125 ^{0}C = 10 kΩ (accept 10.1 kΩ)		½	
		$R_1/R_{th} = 5/1$	formula (stated or implicit)	½	
		$R_1 = R_{th} \times 5/1$			
		$= 10\ k\Omega \times 5$	calculation	½	
		$= 50\ k\Omega$	answer including units	½	
		<u>Alternative method</u>:			
		Highest reference voltage = $9 \times 5/6 = 7.5$ V		½	
		$R_1 = 10 \times 7.5/1.5$	formula (stated or implicit)	½	
		$= 50\ k\Omega$	answer including units	½	**2**
		(ii) $R_{th}/R_1 = 5/1$	formula (stated or implicit)	½	
		$R_{th} = 5/1 \times R_1$			
		$= 5 \times 50\ k\Omega$			
		$= 250\ k\Omega$	answer including units	½	**1**
	(c)	$V_{out} = 9 \times 85/100$			
		$= 7.65$V	calculation (units not necessary	½	
		$R_3 = V/I$	formula, stated or implicit	½	
		$= (7.65 - 1.5) / 30 \times 10^{-3}$ (deduct ½ if 1.5 V not subtracted)	calculation	½	**2**
		$= 205\Omega$ (255 Ω if 1.5 V not subtracted)	answer including units	½	**(6)**

Question		*Mark Allocation*		*Marks*	
6.	**(a)**	LDR resistance = 200Ω	from data book	½	
		Rv = 200/1000 x 8	substitution	½	
		= 1.6 kΩ	answer ½; units ½	1	**2**
	(b)	Maximum output voltage before saturation = 85% of 9V = 7.65V	calculation	½	
		I = V/R	formula stated or implied	½	
		= (7.65 – 0.7)/ 760	substitution	½	
		= 9.14 mA	answer including units	½	**2**
	(c)	(i) I = 9/15	calculation	½	
		= 600 mA	answer	½	**1**
		(ii) h_{FE} = 600/9.14	calculation	½	
		= 65.6	answer	½	**1**
		(iii) 2N3704			**1**
					(7)
7.	(a)	$\Sigma M_H = 0$	formula stated or implicit	½	
		(Fcos30 x 800) + (142cos70 x1100) = (300 x 400)	three terms @ ½ each	1½	
		Fcos30 = 83.22	calculation	½	
		F = 96.1 N	answer, including units	½	**3**
	(b)	$\Sigma F_V = 0$	formula stated or implicit	½	
		R_V + 142cos70 + 96.1cos30 = 300	three components @ ½ each	1½	
		R_V = 168.2 N	answer (units not necessary)	½	
		$\Sigma F_H = 0$	formula stated or implicit (½ if no mark awarded above)		
		R_H + 96.1cos60 = 142cos20	two components @ ½ each	1	
		R_H = 85.4 N	answer (units not necessary)	½	
		$R = \sqrt{(168^2 + 85.4^2)}$	formula and calculation	½	
		= 188 N	answer including units	½	
		tan θ = 168/85.4	substitution	½	
		θ = 63.1° (from horizontal)	answer	½	**6**
					(9)

Question			Mark Allocation	Marks	
10	**(a)**		<u>For AC:</u> $\Sigma F_V = 0$ $F_{AC} \sin 27° = 1{\cdot}18$ — substitution — 1 $F_{AC} = 2{\cdot}6$ kN (TIE) — answer with units — 1 correct nature — 1 <u>For AB:</u> $\Sigma F_H = 0$ $F_{AB} = 2{\cdot}6\cos 27$ — substitution — 1 $F_{AB} = 2{\cdot}32$ kN (STRUT) — answer with units — 1 correct nature — 1 <u>For CB:</u> $\Sigma F_V = 0$ $F_{BC} = 1{\cdot}18$ kN (TIE) — answer with units — 1 correct nature — 1  <u>For CD:</u> $\Sigma F_V = 0$ $F_{CD}\cos 63 = 1{\cdot}18 + 1{\cdot}18$ — 3 terms — 3 $F_{CD} = 5{\cdot}2$ kN (STRUT) — answer with units — 1 correct nature — 1 <u>For CE:</u> $\Sigma F_H = 0$ $F_{CE} = 2{\cdot}32 + 5{\cdot}2\cos 27$ — 2 terms — 2 $F_{CE} = 6{\cdot}95$ kN (TIE) — answer with units — 1 correct nature — 1		**17**
	(b)		 Two sensors — 1 Two signal conditioners — 1 Multiplexer — 1 ADC — 1 Microcontroller — 1 Datalogger — 1		**6**

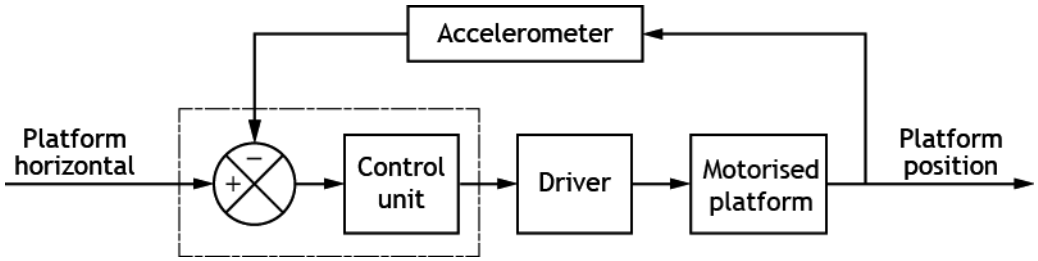
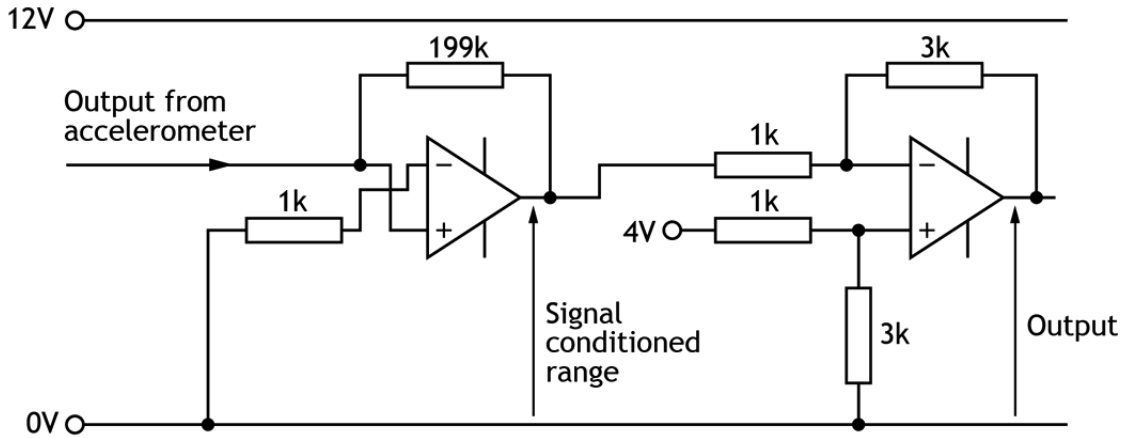
Question			Marks	
11	**(c)**	-When there is too little concrete in the hopper, R_{G2} is of lower resistance than when the correct amount of concrete is in the hopper. -V_1 is less than V_2. -The output of the difference amplifier is positive Any two answers: in total for both	½	
		-The NPN transistor is on, and the green light comes on. complete answer	½	
		-When the amount of concrete in the hopper is within acceptable limits, V_1 is close to V_2. -The output of the difference amplifier is small. either answer	½	
		-Neither of the transistors turns on sufficiently to light up either lamp visibly. complete answer	½	
		-When there is too much concrete in the hopper, R_{G2} is of higher resistance than when the correct amount of concrete is in the hopper. -V_1 is greater than V_2. -The output of the difference amplifier is negative Any two answers: in total for both	½	
		-The PNP transistor is on, and the red light comes on. complete answer	½	**3**
	(d)	$V_1/12 = 120.02/240.02$ $V_1 = 120.02/240.02 \times 12$		
		$V_1 = 6.0005$ V (units not necessary)	½	
		If $V_{out} = 0$ V then $V_2 = V_1$ $V_2 =$ **6.0005 V** (answer including units)	½	**1**
	(e)	(i) $(V_2 - V_1) \times 1000/2 \times (1 + 957/3) = -4$ formula, stated or implicit	½	
		$(V_2 - V_1) \times 1000/2 \times (1 + 319) = -4$ manipulation	½	
		$V_2 - V_1 = -4/(500 \times 320)$ calculation	½	
		$V_2 - V_1 = -0.000025$ calculation	½	
		$V_1 = V_2 + 0.000025$ calculation	½	
		$V_1 =$ **6.000525 V** answer, including units	½	**3**
		(ii) $R_{G2}/120 = V_1/(12-V_1)$ formula, stated or implicit	½	
		$R_{G2} = 120 \times V_1/(12-V_1)$ $R_{G2} = 120 \times 6.000525/5.999475$		
		$R_{G2} =$ **120.021 Ω** answer, including units	½	**1**
	(f)	For 140 kN load, $R_{G2} = 120.02$ Ω; change in resistance = 0.02 Ω	½	
		When red lamp is visibly lit $R_{G2} = 120.021$; change in resistance = 0.021 Ω	½	
		Load when red lamp is visibly lit/140 = 0.021/0.02 formula	½	
		Load when red lamp is visibly lit = 140 × 0.021/0.02 = **147 kN** answer, including units	½	**2** **(20)**

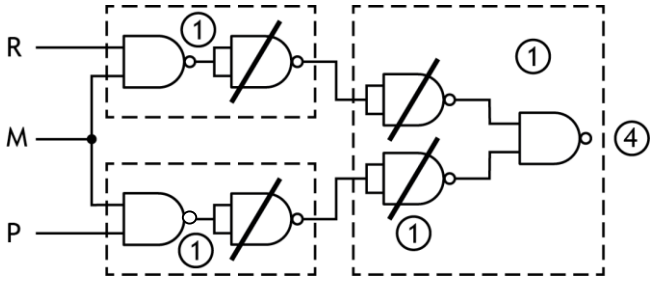
Question			Expected Answer(s)	Max Mark	Additional Guidance
8.	(a)		(R.M)+(P.M) = Z	**3**	1 Mark (R.M) 1 Mark (P.M) 1 Mark for OR Other acceptable answer for full marks: M.(R+P) = Z
	(b)			**4**	2 Marks for both AND gates NAND equivalents 1 Mark OR gate NAND equivalent. 1 Mark for simplification.
	(c)		T = F × R T = (62 × 9·8) × (0·22/2) T = 66·8Nm	**2**	1 Mark for correct substitution. 1 Mark for correct answer with unit.
	(d)		Material A has the highest UTS, it is the strongest and the largest Young's Modulus. Material B is the most brittle and has a lower UTS than A. Material C has the largest plastic range, is the most malleable, is the most ductile and has the lowest UTS. Materials A & B are more elastic than C.	**4**	One property cannot receive more than one mark.
	(e)		Strain = 0·7/100 = 0·007 Stress = 202 × 10^3 × 0·007 = 1414 Area = 3·14 × 15^2/4 = 176·6 Load = Stress × Area = 1414 × 176·6 = 249·7kN	**4**	1 Mark for strain 1 Mark for stress (no unit required) 1 Mark for area (no unit required) 1 Mark for final answer with unit.

Question			Expected Answer(s)	Max Mark	Additional Guidance
	(f)		**Environment effects** Crude oil used to make mineral oil lubricants will become exhausted due to being finite. Biodegradable vegetable oil is protecting the environment. Reduces crop surplus as fields are used to produce natural oil yielding plants. Using vegetable oil increases the longevity of machines due to their superior lubricity. Safer than mineral oils. Non-toxic and does not damage skin tissue. Very high viscosity index which makes vegetable oil's viscosity stable over a wide range of temperatures. **Economic Effects** Biodegradable oils are becoming cheaper for specific applications. Reduced clean-up costs should spillages occur. More economically sustainable than petroleum related lubricants. Often grants and incentives available for the use of experimental chemicals. Alternative option for farmer to boost income.	**3**	1 Mark for each correct or relevant answer.

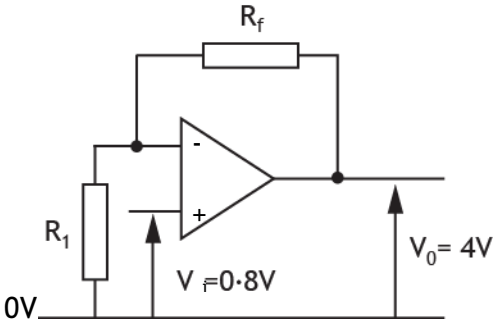
Section 2

Question			Expected Answer(s)	Max Mark	Additional Guidance
6.	(a)		Any of the following statements will receive 1 mark up to a maximum of 8 marks. 1. Pressing either valve A or B will actuate valve C. 2. When C is actuated cylinder 1 instrokes and actuates D. 3. D will actuate E which will cause cylinder 2 to instroke. 4. The system will remain in this state until F or G is actuated. 5. When F or G is actuated E will change state and outstroke cylinder 2. 6. When F or G is actuated H will change state causing main air to reach J. 7. When cylinder 2 actuates J a pilot signal actuates C. 8. When C is actuated cylinder 1 outstrokes and actuates valve K causing H to actuate. 9. Stating or implying that H cuts off the supply of air to J or C. 10. Valve H prevents two pilot signals trying to acutate C at the same time.	8	Appropriate terminology must be evident throughout.
	(b)		Valves A, B, F and G would be replaced by electronic switches. Solenoid actuators would be required on C and E. Microcontroller/ Programmable circuit to control the valves.	2	1 mark for identifying the need for solenoid actuators (or valves). 1 mark for identifying the need for electronic switches at inputs.
	(c)		Skills statements such as: F0 B1 Use nodal analysis to determine the forces inside the members of the structure. F0 B1 Use stress calculations to determine appropriate dimensions for each member. F0 B1 Performing virtual stress analysis on computer modelled designs. F0 B1 Perform force calculations to determine the required size of cylinders and air pressures. F0 B1 Use a sum of moments calculation to determine the reaction forces at the banks. F0 B1 Designing of a pneumatic circuit. Knowledge statements such as: F0 B1 Use knowledge of material properties to select those most appropriate. F0 B1 Knowledge of pneumatic components.	3	1 mark for each valid point relevant to the context. No marks awarded when describing gears and drive systems as this is not in context of question. If candidate refers to it in the machinery involved in the construction; then marks can be awarded.

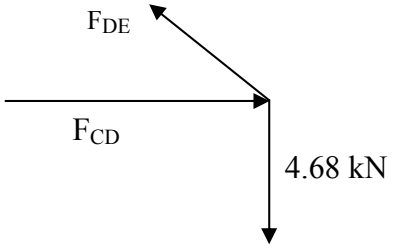
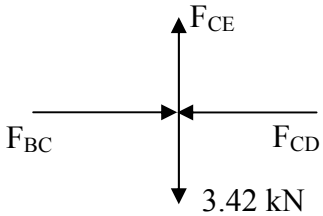
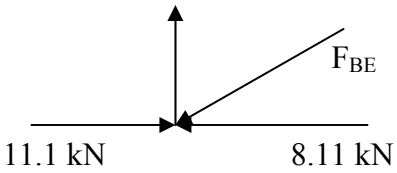
Question			Expected response	Max mark	Additional guidance
9	a			6	1 mark for labelling driver and motorised platform 1 mark for labelling control unit 1 mark for labelling input and output, and adding all connecting arrows 1 mark for completing the feedback loop 1 mark for accelerometer 1 mark for details of error detector
9	b		 Non-inverting op-amp gain = 2/0·01 = 200 (1 mark) 200 = 1 + R_F/R_1 => R_F/R_1 = 199 (so, any values in this ratio) (1 mark) Difference amp gain = R_F/R_1 = 3 (so, any values in this ratio) (1 mark)	6	3 marks for working (as shown) 2 marks for completing diagram (as shown) 1 mark for showing all resistor values on diagram

Question			Expected Answer(s)	Max Mark	Additional Guidance
8.	(a)		(R.M)+(P.M) = Z	**3**	1 Mark (R.M) 1 Mark (P.M) 1 Mark for OR Other acceptable answer for full marks: M.(R+P) = Z
	(b)			**4**	2 Marks for both AND gates NAND equivalents 1 Mark OR gate NAND equivalent. 1 Mark for simplification.
	(c)		T = F × R T = (62 × 9·8) × (0·22/2) T = 66·8Nm	**2**	1 Mark for correct substitution. 1 Mark for correct answer with unit.
	(d)		Material A has the highest UTS, it is the strongest and the largest Young's Modulus. Material B is the most brittle and has a lower UTS than A. Material C has the largest plastic range, is the most malleable, is the most ductile and has the lowest UTS. Materials A & B are more elastic than C.	**4**	One property cannot receive more than one mark.
	(e)		Strain = 0·7/100 = 0·007 Stress = 202 × 10^3 × 0·007 = 1414 Area = 3·14 × 15^2/4 = 176·6 Load = Stress × Area = 1414 × 176·6 = 249·7kN	**4**	1 Mark for strain 1 Mark for stress (no unit required) 1 Mark for area (no unit required) 1 Mark for final answer with unit.

Question			Expected Answer(s)	Max Mark	Additional Guidance
	(f)		**Environment effects** Crude oil used to make mineral oil lubricants will become exhausted due to being finite. Biodegradable vegetable oil is protecting the environment. Reduces crop surplus as fields are used to produce natural oil yielding plants. Using vegetable oil increases the longevity of machines due to their superior lubricity. Safer than mineral oils. Non-toxic and does not damage skin tissue. Very high viscosity index which makes vegetable oil's viscosity stable over a wide range of temperatures. **Economic Effects** Biodegradable oils are becoming cheaper for specific applications. Reduced clean-up costs should spillages occur. More economically sustainable than petroleum related lubricants. Often grants and incentives available for the use of experimental chemicals. Alternative option for farmer to boost income.	**3**	1 Mark for each correct or relevant answer.

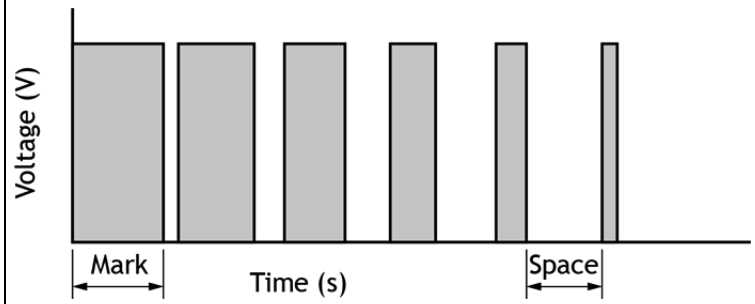
Question			Expected Answer(s)	Max Mark	Additional Guidance
9.	(a)		V_1 = 5v - 0·8v $\frac{V_1}{V_2} = \frac{R_1}{R_2} \Rightarrow \frac{4 \cdot 2}{0 \cdot 8} = \frac{R_1}{250}$ $\Rightarrow 4 \cdot 2 \times 250 = 0 \cdot 8 \times R_1$ $\Rightarrow \frac{1050}{0 \cdot 8} = R_1$ $\Rightarrow 1312 \cdot 5\ \Omega$	**2**	1 mark for finding 4.2v 1 mark for correct answer (or FTE) with units. Full marks for correct answer and units with no working shown. Acceptable answer: 1·31 kΩ = R_1 Alternative solution I=V/R I=0.8/250 = 3.2mA R= V/I = 4.2/3.2x10^{-3} = 1.31k Ω
	(b)	(i)	Non inverting Difference	**1**	
	(b)	(ii)	$A_V = \frac{V_0}{V_1} = \frac{4}{0 \cdot 8} = 5$	**1**	
	(b)	(iii)	 $A_V = 1 + \frac{R_f}{R_1}$ $\frac{R_f}{R_1}$ = 5 – 1 = 4	**2**	**1 mark** for diagram Diagram must include: 0V, and Vi/Vo or 0.8V/4V **1 mark** for any resistor pair in the ratio of 4:1 ie 4k(R_f) 1k(R_1) **if Difference Amp is used resistors will have a 5:1 ratio**

9	**(a)**	A – voltage follower B – difference amplifier	½ ½	**1**
	(b)	Greater change in voltage for a given change in strain (signal amplification) Temperature compensation. either answer		**1**
	(c)	R_{G2} is on top. answer The top surface is under tension, and the strain gauge on this surface will experience a rise in resistance reason	½ ½	**1**
	(d)	$V_2 = 9 \times 120.15/240$ formula, stated or implicit $= 4.505625$ V answer to 6 decimal places, including units	½ ½	**1**
	(e)	$V_{out} = R_f/R_i\ (V_2 - V_1)$ formula, stated or implicit $R_f/R_i = V_{out} / (V_2 - V_1)$ $= 6/(4.505625 - 4.5)$ substitution of values $= 1067$ (accept 1070) answer $R_f = 107$ kΩ, $R_i = 0.1$ kΩ or other suitable pair, higher value in kΩ range	½ ½ ½ ½	**2** **(6)**

Question		Mark Allocation		Marks	
10.	**(a)**	<u>Analysing Node D</u>			
			$\Sigma F_{up} = \Sigma F_{down}$ $F_{DE}\cos 60 = 4.68$ equation $F_{DE} = 4.68/\cos 60$ $F_{DE} = 9.36$ kN (tension) magnitude & units & nature	½ 1	
			$\Sigma F_{right} = \Sigma F_{left}$ $F_{CD} = 9.36\cos 30$ equation $F_{CD} = 8.11$ kN (compression) magnitude & units & nature	½ 1	
		<u>Analysing Node C</u>			
			$\Sigma F_{left} = \Sigma F_{right}$ $F_{BC} = F_{CD}$ $F_{BC} = 8.11$ kN (compression) magnitude & units & nature	 1	
		<u>Analysing Node B</u>			
			$\Sigma F_{left} = \Sigma F_{right}$ $F_{BE}\cos 30 + 8.11 = 11.1$ equation $F_{BE} = 2.99/\cos 30$ $F_{BE} = 3.45$ kN (compression) magnitude & units & nature	1 1	**6**
	(b)	UTS = 430 N/mm2 Force in each bolt = (3.42/4) + 80 = 935 N	from data book calculation answer (units not necessary)	½ ½ ½	
		σ in each bolt = 430/8 = 53.8 N/mm^2	calculation answer (units not necessary)	½ ½	
		$A = F/\sigma$ = 935/53.75 = 17.4 mm^2 $d = \sqrt{((A \times 4)/\pi)}$ $= \sqrt{((17.4 \times 4) / 3.14)}$ = 4.71 mm	 calculation answer (units not necessary) formula, stated or implicit calculation answer, including units	 ½ ½ ½ ½ ½	**5**

Marking Instructions for each question

SECTION 1

Question			Expected response	Max mark	Additional guidance
1	a	i	A	1	1 mark for identifying A.
1	a	ii	Extends least for given loading.	1	1 mark for valid description.
1	b		Yields/changes from elastic to plastic. Beyond X, small extra loading leads to large increase in length.	2	1 mark for description. 1 mark for correct use of terminology (yield, elastic, plastic).
2	a			3	1 mark for labelled axes. 1 mark for labelling of mark and space. 1 mark for showing clearly increasing space and decreasing mark.
2	b		$T = F \times r = 127 \times 0{\cdot}093$ $= 11{\cdot}8$ Nm	2	1 mark for correct formula and substitution. 1 mark for correct answer and units.
3	a		$E_k = 1/2 \times m \times v^2 = 0{\cdot}5 \times 2500 \times (3{\cdot}2)^2 = 12\,800$ J (per second) $E_e = I\,V = 22 \times 230 = 5060$ J (per second) Efficiency = 5060 / 12 800 = 0·40 (40%)	3	1 mark for calculating input kinetic energy. 1 mark for calculating output electrical energy. 1 mark for calculating efficiency.