2010 Technological Studies

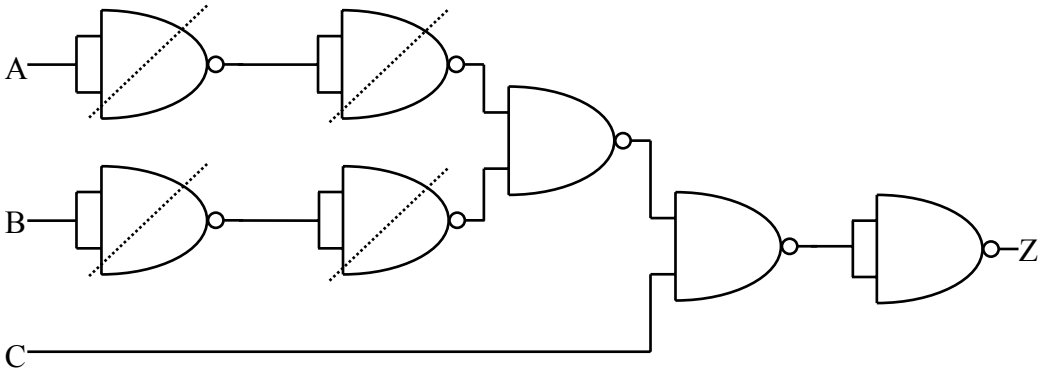
Higher

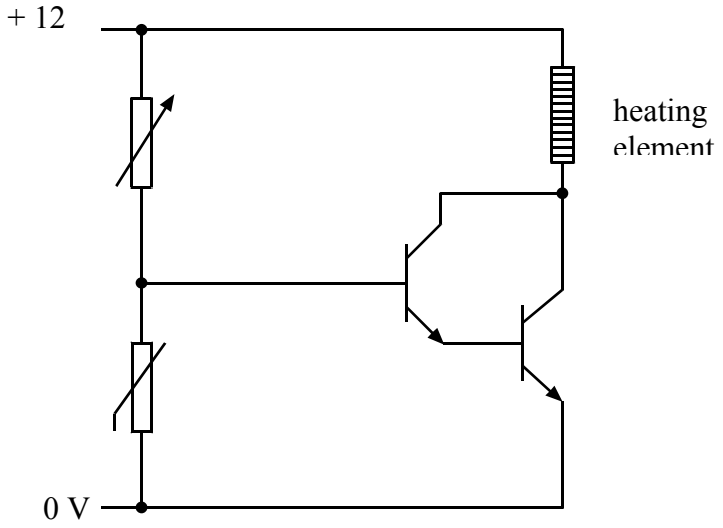
Finalised Marking Instructions

Section A

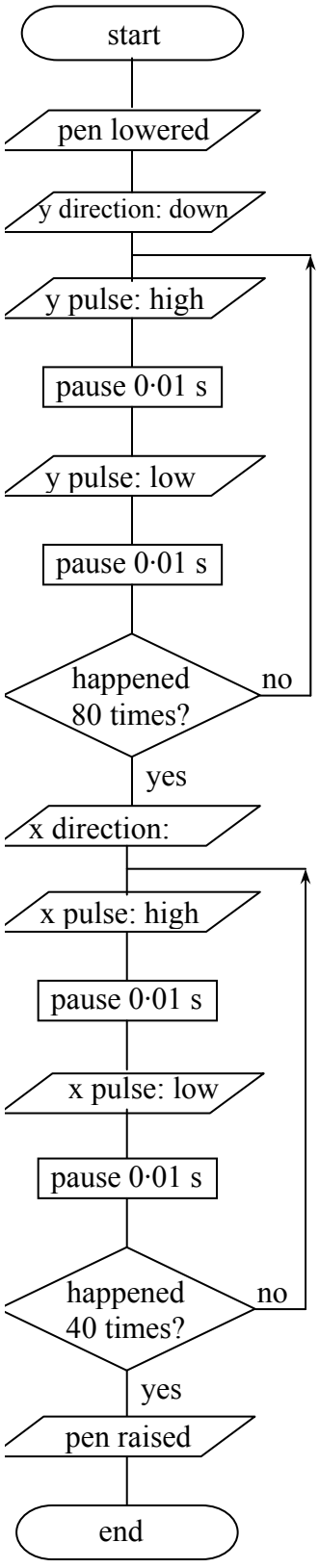
Question		*Mark Allocation*		*Marks*	
1.	**(a)**	**Z = ($\overline{\mathbf{A}}$ + $\overline{\mathbf{B}}$) . C**	two inversions and 'OR' function	½	
			brackets and AND function	½	**1**
	(b)				

A	B	C	**D**	**E**	**F**	**Z**
0	0	0	**1**	**1**	**1**	**0**
0	0	1	**1**	**1**	**1**	**1**
0	1	0	**1**	**0**	**1**	**0**
0	1	1	**1**	**0**	**1**	**1**
1	0	0	**0**	**1**	**1**	**0**
1	0	1	**0**	**1**	**1**	**1**
1	1	0	**0**	**0**	**0**	**0**
1	1	1	**0**	**0**	**0**	**0**

½ for each of columns D, E, F and Z if completely correct		**2**
(c) The inputs A, B and C are all **high (at logic 1)**	½	
The logic value of the output Z is **low (at logic 0)**	½	**1**
(d) 		
two inverter equivalents	½	
OR equivalent ½ and correct connections to inverter equivalents ½	1	
AND equivalent ½ and correct connections to OR equivalent, input C and output ½	1	
cancellation of redundant gates	½	**3**
		(7)

Question			Mark Allocation		Marks	
2.	**(a)**	**(i)**	Variable resistor (potentiometer − no marks) To adjust the threshold (or temperature at which heater comes on) or calibrate		½ ½	**1**
		(ii)	As the temperature falls the resistance of the thermistor rises. As the resistance of the thermistor rises, V_{in} rises.		½ ½	**1**
	(b)		$I = P/V$ $= 100/12$ $=$ **8·33 A**	correct substitution in correct formula, stated or implicit answer, including units	½ ½	**1**
	(c)		$h_{FE} = I_c/I_b$ $= 8{\cdot}33/(4{\cdot}7 \times 10^{-3})$ $=$ **1770**	correct substitution in correct formula, stated or implicit answer, **no** units	½ ½	**1**
	(d)	**(i)**	 • collectors joined together and connected to heating element • emitter 1 to base 2 • emitter 2 to 0 V • base 1 to voltage divider		½ ½ ½ ½	**2**
		(ii)	Darlington pair/Darlington driver	no half marks		**1**
	(e)		$400 \times 80 =$ **32000**	including **no units (**no half marks)		**1**
	(f)		Thermistor resistance at 10 ^{0}C = 20 kΩ (accept 20 – 21 kΩ) $R/20 = 10{\cdot}6/1{\cdot}4$ $R = 10{\cdot}6/1{\cdot}4 \times 20$ $R =$ **151 kΩ**	from Data Booklet recognition of V_{in} = 1·4 V (½); equation (½) answer, including units	½ 1 ½	**2** **(10)**

Question			*Mark Allocation*			*Marks*	
3.	**(a)**		main:	high 6	½ (label 'main' − or any other label – optional)		
				high 2	½		
				for b0 = 1 to 240	½ including 'next b0' below		
				high 3	½ including 'low 3 below		
				pause 10	½ for both pauses totalling 20 ms		
				low 3	mark awarded above		
				pause 10	mark awarded above		
				next b0	mark awarded above		
				low 6	½		
				end	'end' is optional		**3**
	(b)		240 × 0·02 = **4·8 s**		calculation ½, answer including units ½		**1**

Question		*Mark Allocation*	*Marks*
3 cont	**(c)**	 ½ for start box and end box ½ for pen lowered box and pen raised box at end of program ½ ½ for pulse high and pulse low boxes ½ for two pauses adding to 0·02 s allocated above allocated above ½ for '80 times' decision box and backwards arrow, or similar structure − eg 'count = 0', count = count + 1, 'is count = 80?' ½ ½ for pulse high and pulse low boxes ½ for two pauses adding to 0·02 s allocated above allocated above ½ for '40 times' decision box and backwards arrow, or similar structure − eg ''count = 0', count = count + 1, 'is count = 40?' allocated above allocated above	**5** **(9)**

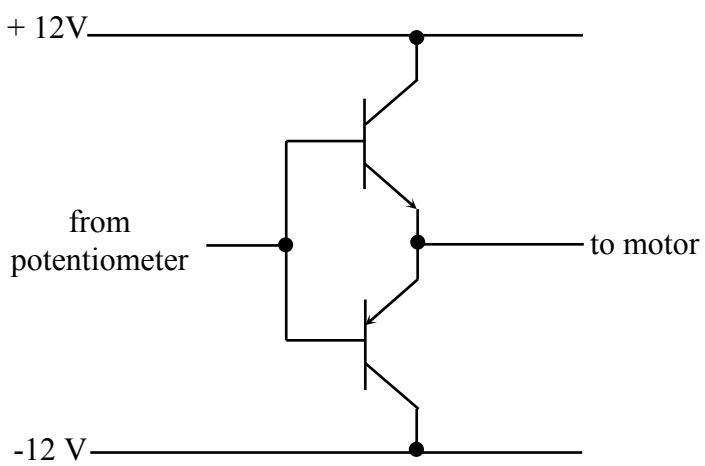
Question			*Mark Allocation*	*Marks*	
4.	**(a)**	**(i)**	$A = \pi d^2/4$ $= 3{\cdot}14 \times 27^2/4$ $= 572mm^2$ answer (units not necessary)	½	
			$\sigma = F/A$ $= 43 \times 10^3/572$ substitution $= 75{\cdot}2\ N/mm^2$ answer (units not necessary)	½ ½	
			$\varepsilon = \Delta l/l$ $= 1{\cdot}5/1400$ substitution $= 0{\cdot}00107$ answer	½ ½	
			$E = \sigma/\varepsilon$ $= 75{\cdot}2/0{\cdot}00107$ substitution $= 70{\cdot}2\ kN/mm^2$ answer including units	½ ½	
			Aluminium Alloy answer	½	**4**
		(ii)	$F = \sigma_y \times A$ $= 250 \times 572$ substitution **= 143 kN** answer including units	½ ½	**1**
	(b)		Consequences of failure (human and financial) Overloading Exceptional loads: weather (snow, ice, high winds), tides, currents, impacts Poor workmanship Poor materials Deterioration over time (corrosion, etc) any 2 answers ½ each		**1** **(6)**

Question			Mark Allocation		Marks	
5.	**(a)**		$V_{out} = -R_f(V_1/R_1 + V_2/R_2) \times -R_f/R_i$ $= -12\ (5/6 + 5/24) \times -1$ — correct substitution		½	
			$= \mathbf{12{\cdot}5\ V}$ — calculation		½	
			Max V_{out} = 85% of 12V — formula, stated or implicit		½	
			= **10·2 V** — answer, including units		½	**2**
	(b)					

Pin 6	Pin 5	Pin 4	V_{out}(V)			
0	0	0	0	}	first 2 lines (no ½ marks)	1
0	0	1	2·5			
0	1	0	5	}	last 3 lines (no ½ marks)	1 **2**
0	1	1	7·5			
1	0	0	10			

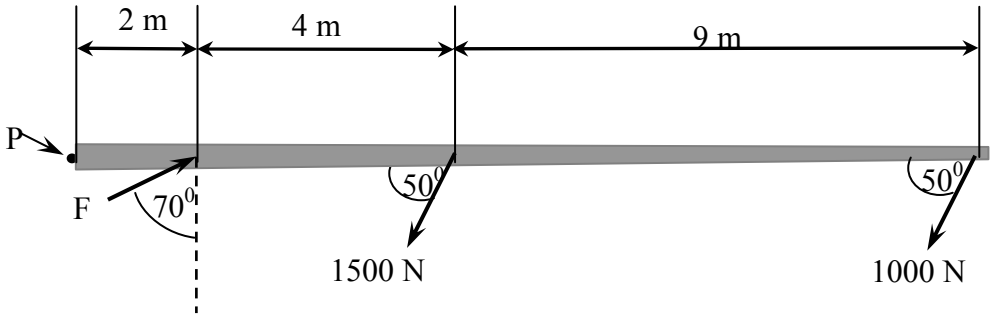
	(c)	**(i)**	Soft starts/starts softly (1 mark) **or** Accelerates/builds up speed (½) slowly/gradually/softly (½)		**1**
		(ii)	Avoids wear/damage to the motor/mechanism (no ½ marks)		**1**
	(d)		High torque (at low speeds) ½ as motor always has 12V across terminals when switched on. ½ Finer control of motor speed/more increments ½ as mark/space ratio can be changed by small amounts. ½ Easier to program ½ as fewer output pins are required. ½ Simpler circuitry ½ as no D to A converter required. ½ Any two pairs of answers		**2** **(8)**

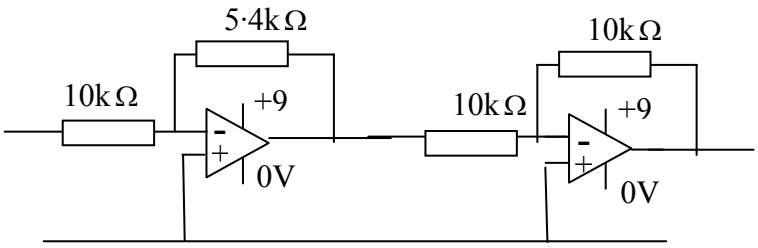
Question			*Mark Allocation*		*Marks*	
6.	**(a)**	**(i)**	BC = tan30 × 2			
			= 1·15m	answer (units not necessary)	½	
			ΣM_B = 0			
			$R_C \times 1{\cdot}15$ = 1·2 × 2	moments two @ ½ mark each	1	
			R_C = 2·4/1·15			
			R_C = **2·08 kN**	answer including units	½	**2**
		(ii)	$R_B = \sqrt{(1{\cdot}2^2 + 2{\cdot}09^2)}$	substitution of values	½	
			R_B = **2·40 kN**	answer including units	½	**1**
	(b)		No forces in member	no ½ marks		**1**
	(c)		<u>Analysing Node A</u>			
			ΣF_V = 0	(½ mark if no other mark awarded)		
			F_{AD} = 1·2/cos60	calculation	½	
			= **2·40 kN Tie**	nature (½) answer including units (½)	1	
			ΣF_H = 0	(½ mark if no other mark awarded)		
			F_{AC} = 2·4 × cos30	calculation	½	
			= **2·08 kN Strut**	nature (½) answer including units (½)	1	**3**
						(7)
7.			main: low 3	½ (mark for label 'main' awarded below)		
			gosub adcread	½		
			b5 = b4	½		
			high 3	½		
			gosub adcread	½		
			if b5 > b4 then fwd	1		
			if b5 < b4 then bck	1		
			low 6 } low 7 }	½		
			goto main	½ (with label 'main' at top of program)		
			fwd: high 7 } low 6 }	½		
			goto main	(mark awarded below)		
			bck: high 6 } low 7 }	½		
			goto main	½ (including 'goto main' above)		
						(7)

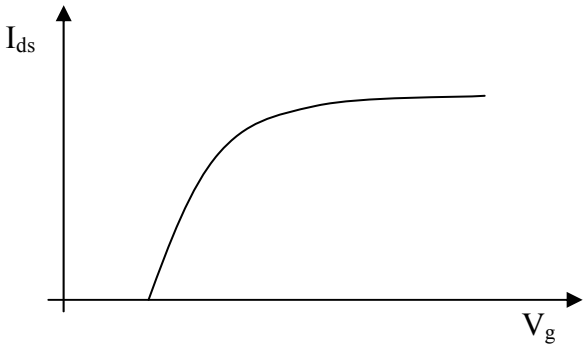
Question			Mark Allocation		Marks
8.	**(a)**		**Push-pull driver** no half marks		**1**
	(b)				
			• two transistors in series between the power supply rails • an NPN and a PNP transistor • NPN & PNP transistors in the correct positions • emitters connected together • connection of emitters to motor • bases joined together, and connection to potentiometer	½ ½ ½ ½ ½ ½	**3**
	(c)		**0 V** no half marks		**1**
	(d)		• The motor starts to turn to extract air. • The further the dial is turned, the faster the motor turns. • When the dial reaches "full speed extract" position, the motor turns at full speed. any two answers @ ½ mark each		**1** **(6)**

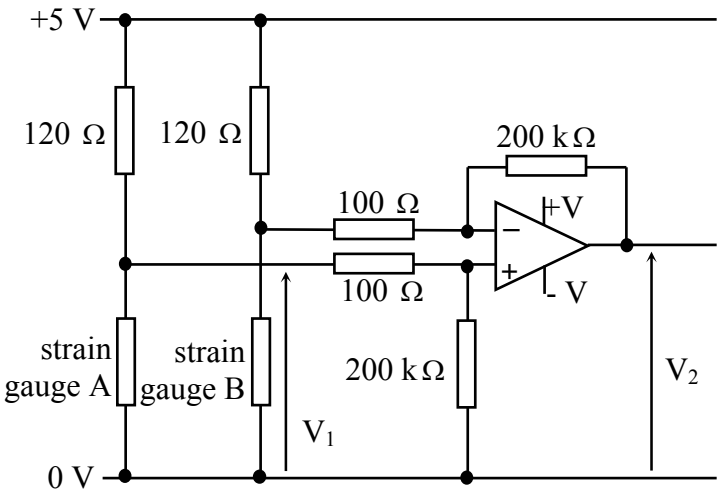
Section B

Question			Mark Allocation		Marks	
9.	**(a)**		$R_{ref}/5{\cdot}6 = R_{(tank\ thermistor)}/5{\cdot}6$	formula, stated or implicit	½	
			R_{ref} = 4·8 k Ω (accept 4·4 k Ω - 4·9 k Ω)	(from Data Booklet)	½	**1**
	(b)	**(i)**	Resistance of tank thermistor @ 25 ^{0}C = 50 k Ω	(from Data Booklet)	½	
			V_1 (Voltage at inverting input) = 56/106 × 24 V = 12·7 V		½	
			Op-amp output voltage, V_{out} = Vp + 0·7 V = 6·7 V		½	
			$V_{out} = R_f/R_i(V_2 - V_1)$	formula, stated or implicit	½	
			$V_{out}/(R_f/R_i) = (V_2 - V_1)$			
			$V_{out} \times (R_i/R_f) + V_1 = V_2$			
			$V_2 = V_{out} \times (R_i/R_f) + V_1$			
			$V_2 = 6{\cdot}7 \times 100/460 + 12{\cdot}7$	credit for substitution and manipulation of formula	½	
			V_2 = 14·2 V	answer (units not essential)	½	
			Resistance of panel thermistor/56 = 9·8/14·2 V			
			Resistance of panel thermistor = 56 × 9·8/14·2 = 38·6 k Ω	answer (units not essential)	½	
			Collector temperature = **30 ^{0}C** (accept 30 - 33 ^{0}C)	(from Data Booklet)	½	**4**
		(ii)	Resistance of tank thermistor = 50 k Ω	(from Data Booklet) (if not awarded above)	(½)	
			V_1 (Voltage at inverting input) = 56/106 × 24 V = 12·7 V	(if not awarded above)	(½)	
			At saturation, V_{out} = 85% × 24 = 20·4 V		½	
			Thermistor resistance @ 40 ^{0}C = 30 k Ω (accept 28 – 30 k Ω)	(from Data Booklet)	½	
			Voltage at non-inverting input, $V_2 = 56/(56 + 30) \times 24 = 15{\cdot}6$ V (accept 16 V, etc)		½	
			$V_{out} = R_f/R_i(V_2 - V_1)$	formula, stated or implicit	½	
			$R_f = V_{out} \times R_i/(V_2 - V_1)$			
			$R_f = 20{\cdot}4 \times 100/(15{\cdot}6 - 12{\cdot}7)$	substitution and manipulation of formula	½	
			R_f = 703 k Ω		½	**3**
	(c)	**(i)**	The tank temperature is low, so the relay contacts are closed. The panel temperature and the tank temperatures are the same, so the output of op-amp 2 is 0 V, and the pump is off.	two answers @ ½ each		**1**
		(ii)	The tank temperature is still not high, so the relay contacts are closed. The panel temperature is greater than the tank temperatures, so the output of op-amp 2 is positive, and the pump is on.	two answers @ ½ each		**1**
		(iii)	The temperature in the tank is very high, so the relay contacts are open, and the pump is off. The panel temperature is greater than the tank temperatures, so the output of op-amp 2 is positive.	any two answers @ ½ each		**1**

Question			Mark Allocation	Marks	
9 cont	**(d)**	**(i)**			
			Taking Moments about the pivot:		
			$\Sigma M_{cw} = \Sigma M_{ac}$ formula, stated or implicit	½	
			$(1000\cos 40 \times 15) + (1500\cos 40 \times 6) = F\cos 70 \times 2$ ½ mark for each correct term	1½	
			$11490 + 6894 = 2F\cos 70$		
			$F = 18384/(2\cos 70)$ manipulation of equation	½	
			$F =$ **26·9 kN** answer, including units	½	**3**
		(ii)	Taking vertical components		
			$\Sigma F_{(up)} = \Sigma F_{(down)}$ ½ mark in total for this line & $\Sigma F_{(left)} = \Sigma F_{(right)}$ (below)		
			if no other marks allocated	(½)	
			$26900\cos 70 = R_V + 1500\cos 40 + 1000\cos 40$	½	
			$R_V = 9200 - 1915$		
			$R_V = 7{\cdot}29$ kN units not necessary	½	
			Taking horizontal components		
			$\Sigma F_{(left)} = \Sigma F_{(right)}$		
			$R_h + 1500\cos 50 + 1000\cos 50 = 26900\cos 20$	½	
			$R_h = 25278 - 1607$		
			$R_h = 23{\cdot}7$ kN units not necessary	½	
			$R^2 = 7{\cdot}29^2 + 23{\cdot}7^2$	½	
			$R =$ **24·8 kN** answer, including units	½	**3**
	(e)		$\sigma_{sw} = \sigma_{ultimate}$/Factor of Safety		
			$\sigma_{sw} = 680/12$ (from Data Booklet – any value in range 680 - 2400)	½	
			$= 56{\cdot}7$ N/mm^2 answer, units not necessary	½	
			$A = F/\sigma$ formula, stated or implicit	½	
			$= 6000/56{\cdot}7$		
			$= 106$ mm^2 answer, units not necessary	½	
			$\pi d^2/4 = 106$ formula and substitution, stated or implicit	½	
			$d^2 = 106 \times 4/\pi$		
			$d =$ **11·6 mm** answer, including units	½	**3**
					(20)

Question			Mark Allocation	Marks	
10.	**(a)**	**(i)**	• Brings signal into appropriate range for A to D converter.	1	
			• Will attenuate the signal to bring it below ADC reference voltage.	½	
			• Will amplify a very small signal in order to use appreciable proportion of ADC reference signal.	½	**2**
		(ii)	Recognises inputs, respond to these in a way as dictated by the program, controls outputs as appropriate.		**1**
	(b)		Av = 2·71/5 = 0·54 Voltage gain calculation	½	
			Two inverting amplifiers, one with gain -0·54, and one with gain of -1.	½	
			First amplifier, Rf = 5·4kΩ, Ri=10kΩ (or any other pair in kΩ range)	½	
			Second amplifier, Rf = 10kΩ, Ri=10kΩ (or any other pair in kΩ range)	½	
			Two correct inverting amplifier circuits with resistor values in correct places @ ½ each.	1	**3**
					
	(c)		10011010 = 154	½	
			Input voltage = 154/255 × 3·8 = **2·29V**	½	**1**

Question			Mark Allocation			Marks	
10 cont	**(d)**		main:	if pin0 = 0 then main	½		
				high 7	½		
			boil:	gosub adcread	½		
				if data < 182 then boil	½		
				MINUTE = 0	½ (both minute = 0)		
			wait1:	gosub timer	½ (both *gosub timer*)		
				if MINUTE < 10 then wait1	½		
				pins = %0111 0000	½		
				MINUTE = 0	(mark awarded above)		
			wait2:	gosub timer	(mark awarded above)		
				if MINUTE = 60 then led1off	½		
				if MINUTE = 120 then led2off	½	(destination/label must be correct)	
				if MINUTE = 180 then alloff	½		
				goto wait2	½ (all three *goto wait2*)		
			led1off:	pins = %0011 0000 (or low 6)	½		
				goto wait2	(mark awarded above)		
			led2off:	pins = %0001 0000 (or low 5)	½		
				goto wait2	(mark awarded above)		
			alloff:	pins = %0000 0000 (or low 4)	½		
				goto main	½		**8**
	(e)		I_b = (5 – 0.7)/600			½	
			= 7·17mA		units not necessary	½	
			I_c = (6 – 0·2)/24			½	
			= 242mA		units not necessary	½	
			h_{FE} = I_c/I_b = 242/7·17			½	
			= **33·8**		answer, **no** units	½	**3**
	(f)						
					two axes labelled	½	
					Vt indicated –label not necessary	½	
					saturation	½	
					sloping section	½	**2**
							(20)

Question			Mark Allocation		Marks	
11.	**(a)**	**(i)**	A $= 6^2 - 4^2 = 20\ mm^2$		½	
			σ = F/A	formula, stated or implicit	½	
			= 900/20	substitution	½	
			= **45 N/mm^2**	answer, including units	½	**2**
		(ii)	$\varepsilon = \sigma/E$			
			= 45/196000	correct substitution into correct formula	½	
			= **230×10^{-6}**	answer, **no** units	½	**1**
	(b)		Strain gauge B is included for temperature compensation	(no half marks)		**1**
	(c)	**(i)**	$\Delta R = 2\varepsilon \times R$			
			$= 2 \times 5{\cdot}00 \times 10^{-4} \times 120$	correct substitution into correct formula	½	
			$= 0{\cdot}12\ \Omega$	answer, units not necessary	½	
			$R = 120 + 0{\cdot}12 = 120{\cdot}12\ \Omega$			
			$V_2 = 120{\cdot}12/240{\cdot}12 \times 5$	correct substitution into correct formula	½	
			V_2 = **2·50125 V**	answer, including units **and 5 decimal places**	½	**2**
		(ii)	$V_{out} = R_f/R_i(V_2 - V_1)$	formula, stated or implicit	½	
			$R_f/R_i = V_{out}/(V_2 - V_1)$			
			$R_f/R_i = 2{\cdot}5/(2{\cdot}50125 - 2{\cdot}5)$			
			$R_f/R_i = 2{\cdot}5/0{\cdot}00125$	correct substitution and manipulation	½	
			R_f/R_i = 2000 (resistor ratio)	correct answer	½	
						
				correct difference amplifier configuration	½	
				correct resistor ratio (½) with resistors in correct places (½)	1	**3**

Question			Mark Allocation	Marks	
11 cont	**(d)**		• As the strain in the support bar rises, the input voltage to the inverting input of the comparator (or: op. amp. in processing sub-system 2) rises.	½	
			• The potentiometer (R_v) sets the threshold strain (or: the potentiometer sets the reference voltage to the non-inverting input of the comparator).	½	
			• When the strain rises above the threshold (or: when the voltage on the inverting input rises above the voltage on the non-inverting input) the op. amp output goes low (or: is 0 V).		
			or		
			• When the strain rises above the threshold the transistor switches off.		
			either answer @ ½ mark	½	
			• When the strain rises above the threshold the voltage at the output (of processing sub-system 2) is high/5V or pin3 is high.	½	**2**
	(e)		80 × 10 ms = **0·8 s** (0·79 s - ½ mark)		**1**
	(f)		• After 5 seconds, when a person is detected, the motor starts at a low speed (or: with a motor power value of 20).	½	
			• Every 10 milliseconds the motor power value increases by 1 (or: the speed increases slightly).		
			or		
			• The motor power value increases (or: motor speed increases) until the motor is running at full speed.		
			or		
			• 0·8 seconds after starting, the motor is running at full speed.		
			any two answers out of three @ ½ each	1	
			• 6 seconds after the person is detected (or: after the motor starts) the door is obstructed, and the motor stops.	½	
			• 3 seconds later the motor then starts slowly again, and speeds up to full speed.	½	
			• 7 seconds after starting again the motor stops (or 8 seconds after the door is no longer obstructed).	½	**3**
	(g)		The potentiometer would have to be adjusted (½) to give a higher (reference) voltage to the non-inverting input (½).		**1**
	(h)		Analogue to Digital converter (ADC) (½) to convert the analogue signal from processing sub-system 1 into a digital value for the microcontroller (½).		**1**
	(i)		A subprocedure (such as adcread) would need to be run to get a digital value from the Analogue to Digital converter (½) and store it in the microcontroller memory (½). This value would need to be compared with a reference value (½). The value from the ADC would need to be compared with the reference to determine whether or not there was an obstruction (½).		**2**
	(j)		Changes in software are easier to make as they involve changing the program and downloading the new version (½), whereas changes to hardware involve changing actual components (½).		**1**
					(20)

[END OF MARKING INSTRUCTIONS]