2012 Technological Studies

Higher

Finalised 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

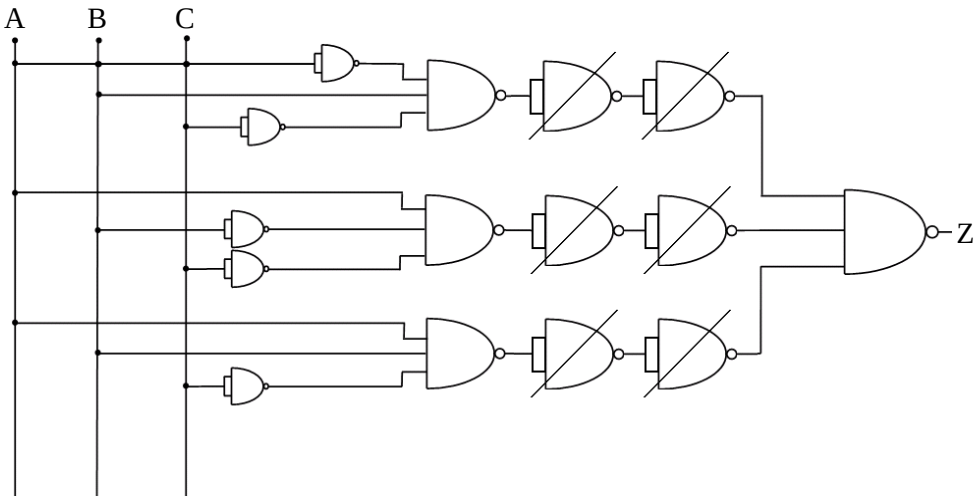
1 — **3**

(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)

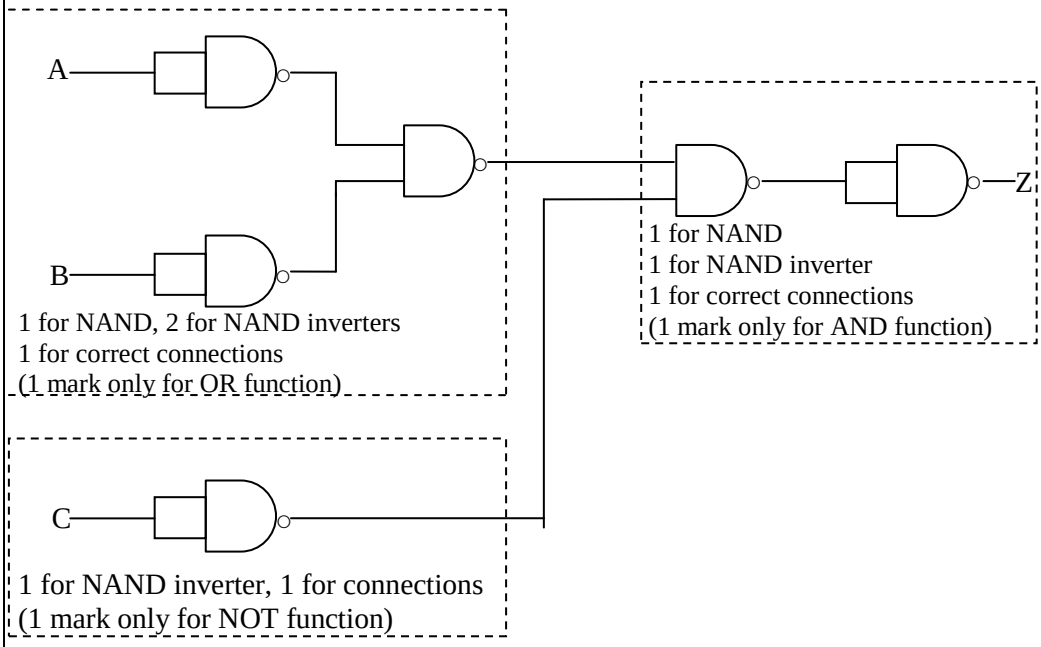


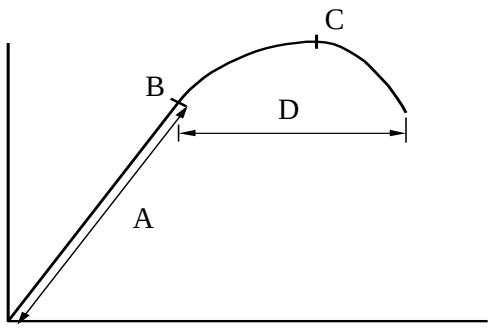
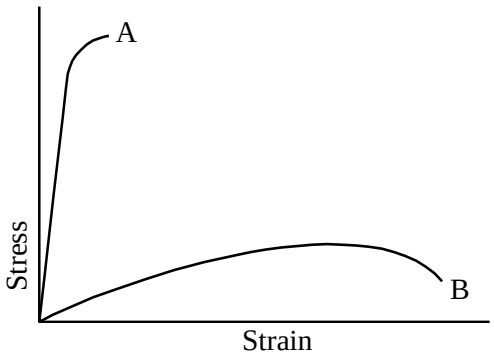
AND gate equivalents and connections — 3
NOT gate equivalents and connections — 3
OR gate equivalent and connections — 2
Cancellation of redundant gates — 1 — **9**

(16)

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

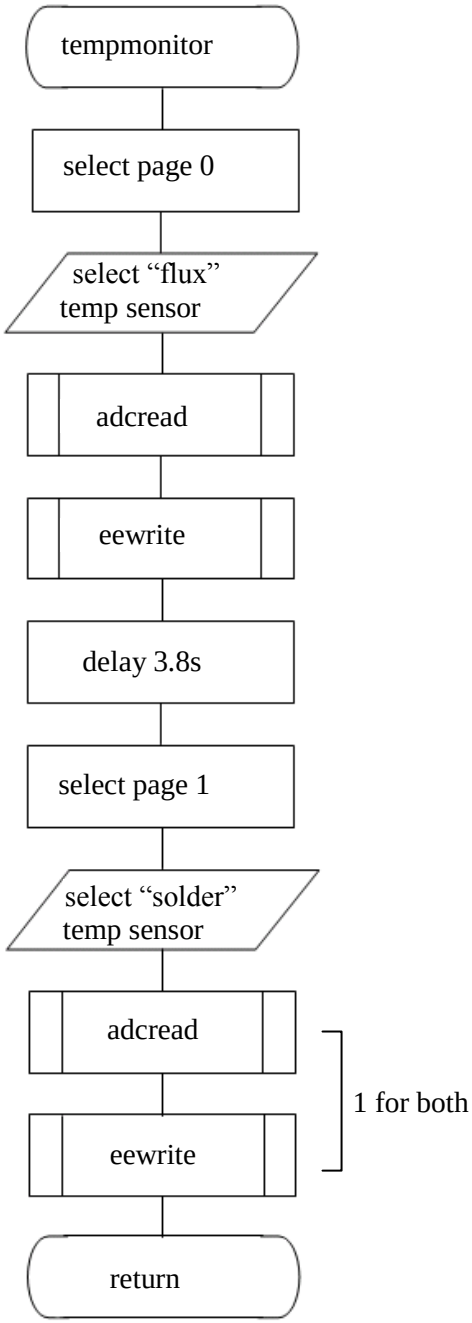
Supplementary Sheet

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

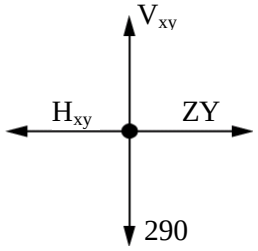
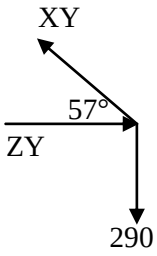
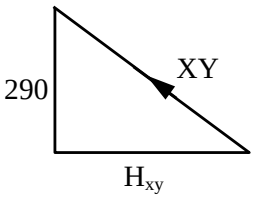
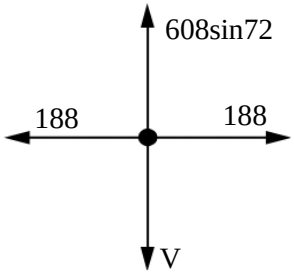
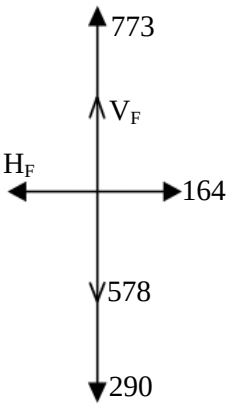
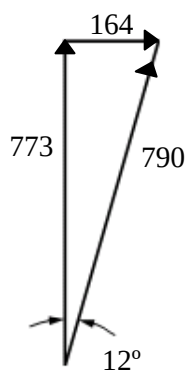
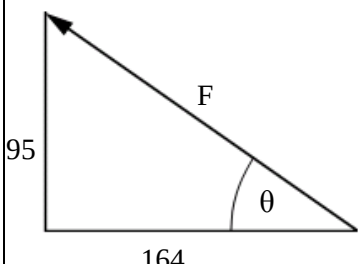
Question		*Mark Allocation*	*Marks*	
2.	**(a)**	$A = 100\ mm^2$ answer	1	
		$\sigma = \frac{F}{A}$		
		$= \frac{1000}{100} \quad \frac{2000}{100} \quad \frac{3000}{100} \quad \frac{4000}{100} \quad \frac{5000}{100}$		
		$= 10\ N/mm^2 \quad 20\ N/mm^2 \quad 30\ N/mm^2 \quad 40\ N/mm^2 \quad 50\ N/mm^2$		
		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	
		$E = \frac{\sigma}{\varepsilon} = \frac{20}{2 \times 10^{-4}}$ (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)

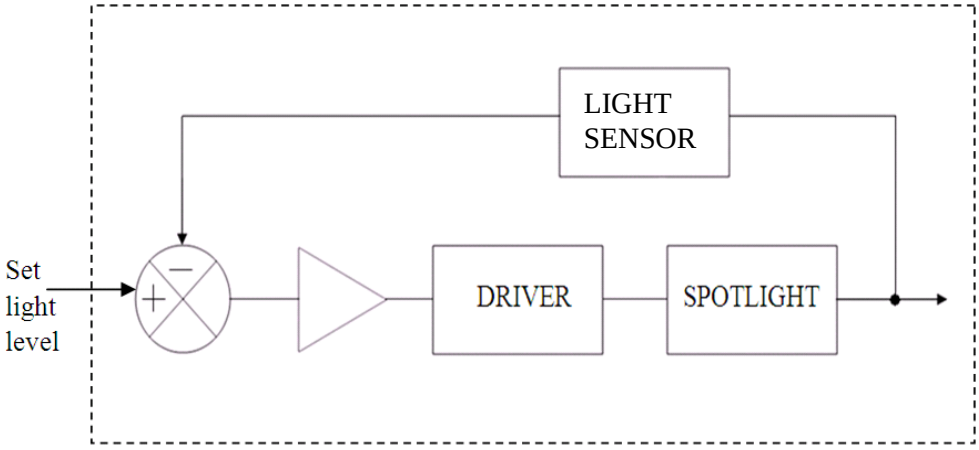
Question		Mark Allocation	Marks	
3.	**(a)**	Close: TIME = 10	1	
		for b0 = 1 to 20 (or COUNTER) Including 'next b0' below	1	
		for b1=1 to 10	1	
		high 4		
		pause 10 > both for 1 mark	1	
		low 4	1	
		pause TIME	1	
		next b1	1	
		TIME = TIME + 2	1	
		if pin2 = 1 then finish	2	
		next b0		
		finish: return 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 $= 10 + (2 \times 20) = 50\,\text{ms}$		
		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)	$V_{be2} = 0.7\,\text{V}$ by inspection	1	
		$V_{3600} = 2.3 - 1.4 = 0.9\,\text{V}$ calculation	1	
		$I_{b1} = \frac{V}{R} = \frac{0.9}{3600}$ all substitutions	1	
		$I_{b1} = 0.25\,\text{mA}$ answer	1	
		$I_{b2} = 2.5 \times 10^{-6} \times 80$ substitutions	1	
		$= 0.02\,\text{A}$ answer	1	
		Pump resistance $R_P = \frac{P}{I^2}$		
		$= \frac{500}{2.13^2}$ substitutions	1	
		$= 110\,\Omega$ answer	1	
		$h_{FE_2} = \frac{I_c}{I_b} = \frac{2{\cdot}13}{0{\cdot}02}$ substitutions	1	
		= 106.5 answer	1	
		Overall current gain = $h_{FE1} \times h_{FE2}$		
		= 80 × 106·5 substitutions	1	
		= 8520 answer	1	**12**
		See Supplementary Sheet, page 6		**(15)**

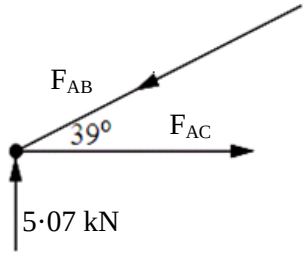
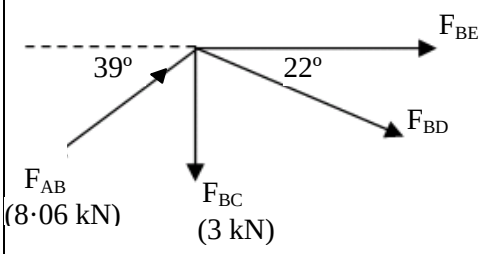
Question		*Mark Allocation*		*Marks*	
4.		**Quantity**	**Working**		
		Vin	2·3 V		
		Vbe_2	0·7 V by inspection	1	
		Ib_1	$V_{3600} = 2.3 - 1{\cdot}4 = 0{\cdot}9$ V Calculation	1	
			$Ib_1 = \frac{V}{R} = \frac{0{\cdot}9}{3600}$ All substitutions	1	
			Ib_1 = **0·25 mA** Answer	1	
		Ib_2	$Ib_2 = 0{\cdot}25 \times 10^{-3} \times 80$ Substitutions	1	
			= **20 mA (0·02 A)** Answer	1	
		I_p	2·13 A		
		Pump Resistance	$Rp = \frac{P}{I^2}$		
			$\frac{500}{2{\cdot}13^2}$ Substitutions	1	
			= **110 Ω** Answer	1	
		h_{FE1}	80		
		h_{FE2}	$h_{FE2} = \frac{I_c}{I_b} = \frac{2{\cdot}13}{0{\cdot}02}$ Substitutions	1	
			= **106·5** (no unit) Answer	1	
		Overall Current Gain	Overall gain: $h_{FE1} \times h_{FE2}$		
			= 80 × 106·5 Substitutions	1	
			= **8520** (no unit) Answer	1	
					(12)

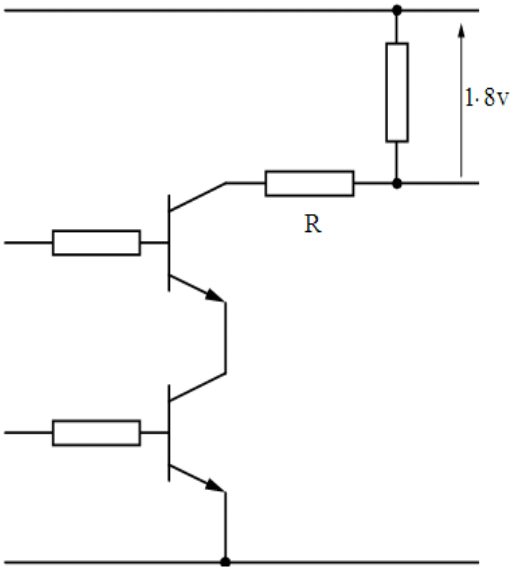
Question		*Mark Allocation*	*Marks*	
5.	**(a)**	To provide an appropriate signal within the correct voltage range.	1	**1**
	(b)	Data is held whether powered or not (ie non volatile) Data may be erased (electronically).	1 1	**2**
	(c)	How rapidly data is changing; memory available; consequence of missing an event (any 2 acceptable)	2	**2**
	(d)		1 1 1 1 1 1 1 1 1 1	**10**
		If flowchart box is incorrect, do not award a mark (to a maximum of 4)		**(15)**

Question			*Mark Allocation*		*Marks*	
6.	**(a)**		Summing		1	**1**
	(b)	(i)	$\frac{R}{120} = \frac{11.98}{0.02}$	substitutions	1	
			$R = 71880\ \Omega = 71.9\ \text{k}\Omega$	answer	1	**2**
		(ii)	$\frac{71880}{R_{g1}} = \frac{11.97}{0.03}$	substitutions	1	
			$R_{g1} = \frac{71880 \times 0.03}{11.97}$			
			$R_{g1} = 180.2\ \Omega$	answer	1	**2**
		(iii)	$R_2 = 5 \times 2 = 10\,\text{k}\Omega$	answer	1	
			$R_1 = \frac{100}{40} \times 5 = 12.5\,\text{k}\Omega$	answer	1	**2**
	(c)		$V_2 = \frac{12500}{71880 + 12500} \times 12$	substitutions	1	
			$= 0.021\ \text{V}$	answer	1	
			$V_{out} = (0.03 \times (-40)) + (0.021 \times (-50)) + (0.02 \times (-100))$	substitutions	3	
			OR			
			$V_{out} = -500\left(\frac{0 \cdot 03}{12 \cdot 5} + \frac{0 \cdot 021}{10} + \frac{0 \cdot 02}{5}\right)$			
			$V_{out} = -1.2 - 1.05 - 2$	simplification	1	
			$= -4.25\,\text{V}$	answer	1	**7**
						(14)

Question		Mark Allocation			Marks	
7.	**(a)**	(i)	NODE Y  	$V_{xy} = 290$ $H_{xy} = ZY$  		
			 	$XY = \frac{290}{\sin 57}$ substitution $= 345.7$ N answer $YZ = H_{XY} = 345.7\cos 57$ substitution $= 188$ N answer	1 1 1 1	
			$H_{XZ} = 188$ $XZ = \frac{188}{\cos 72}$ $= 608$ N	substitution answer	1 1	**6**
		(ii)	NODE Z  	V = 608sin72 V = 578 N answer	1	
			NODE X  	Applied force 790 N Components F_n = 164 N; F_v = 773 N  H_F = 164 $V_F = (578 + 290) - 773$ = 95 $F = \sqrt{95^2 + 164^2}$ = 190 N	1 1 1 1 1	**6**
		(iii)	 	$\tan\theta = \frac{95}{164}$ $\theta = 90 - 30.1$ $\theta = 59.9°$ substitution answer	1 1	**2**
						(14)

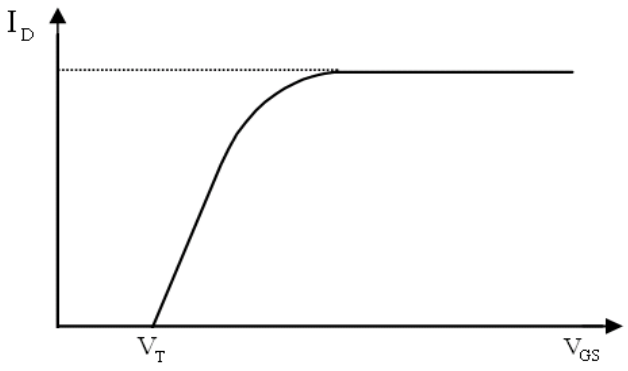
Question		Mark Allocation		Marks	
8.	**(a)**				
		1 for set light level 1 for error detector 1 for error amplifier 1 Driver 1 Spotlight 1 Light Sensor 1 for Light Sensor connections		1 1 1 1 1 1 1	**7**
	(b)	$V_{ref} = \frac{2}{2+4.8} \times 12$	substitution	1	
		$= 3.53\,V$	answer	1	**2**
	(c)	At 400 Lux R_{LDR} = 310 Ω (accept 300–320)	from Data Book	1	
		Difference amplifier gain $= \frac{120}{10} = 12$	gain calculation	1	
		$V_0 = A_V (V_{ref} - V_{in})$			
		So $V_{ref} - V_{in} = \frac{8}{12} = 0.667\,V$	error calculation	1	
		$V_{LDR} = 3.53 - 0.667$	substitution	1	
		$= 2.86\,V$	answer	1	
		$R = \frac{310 \times 2{\cdot}86}{9{\cdot}14}$	substitution	1	
		$= 97.0\Omega$	answer	1	**7**
					(16)

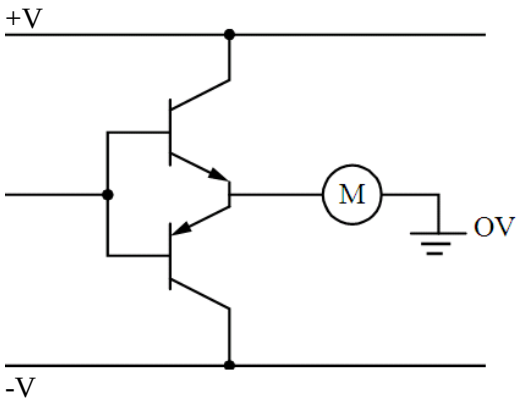
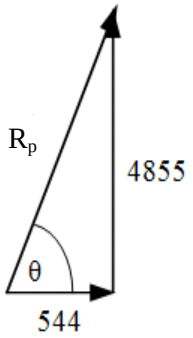
Question		Mark Allocation		Marks	
9.	**(a)**	About R_2: $\Sigma M = 0$			
		$37.1R_1 = (19.6 \times 4.8) + (31.3 \times 3)$	substitutions	1	
		R_1 = 5·07 kN	answer	1	**2**
	(b)	NODE A			
					
		$5{\cdot}07 = AB\sin 39^\circ$	substitutions	1	
		F_{AB} = 8.06 kN STRUT	force including unit	1	
			nature	1	
		$AC = 8.06\cos 39$	substitutions	1	
		F_{AC} = 6.26 kN TIE	force, unit	1	
			nature	1	
		NODE B			
					
		F_{BC} = 3 kN		1	
		$\Sigma F_V = 0$ (stated or implicit)		1	
		$F_{AB}\sin 39 - F_{BC} - F_{BD}\sin 22 = 0$		3	
		$F_{BD} = \dfrac{8.06\sin 39 - 3}{\sin 22}$		1	
		$F_{BD} = 5.53\,\text{kN TIE}$	force, unit	1	**14**
			nature	1	
	(c)	$\varepsilon = \dfrac{\Delta l}{l}$			
		$= \dfrac{2{\cdot}5}{13700}$	substitutions	1	
		$= 182 \times 10^{-6}$	answer	1	
		$E = 70 \times 10^3\ \text{N/mm}^2$	value from Data Book	1	
		$\sigma = E\,\varepsilon$			
		$= 70 \times 10^3 \times 182 \times 10^{-6}$	substitutions	1	
		$= 12.77\ \text{N/mm}^2$	answer	1	
		$A = \dfrac{F}{\sigma}$			
		$= \dfrac{8000}{12{\cdot}77}$	substitution	1	
		$= 626.5\ \text{mm}^2$	answer	1	
		$\text{Area} = \dfrac{\pi D^2}{4} - \dfrac{\pi d^2}{4}$			
		$d = \sqrt{D^2 - \dfrac{4A}{\pi}}$			
		$d = \sqrt{75^2 - \dfrac{4 \times 626.5}{\pi}}$	substitutions	1	
		d = 69·5	answer	1	
		Min wall thickness = $\dfrac{75 - 69.5}{2} = 2.75\,\text{mm}$	substitutions	1	
			answer	1	**11**

Question		Mark Allocation		Marks	
	(d)	display arrow: for b0 = 1 to 50 pins = % 10000001 } given pause 5			
		pins = % 01010010		1	
		pause 5			
		pins = % 00110100		1	
		pause 5			
		pins = % 01111000		1	
		pause 5	(3 × pause 5)	1	
		next b0		1	
		return		1	**6**
	(e)				
			$V_R = 12 - 1.8 - (2 \times 0{\cdot}2)$		
			= 9.8 V answer	1	
			$I_R = 5 \times 20$		
			= 100 mA (units not required)	1	
			$R = \frac{9.8}{0.1}$	1	
			$R = 98\Omega$ answer	1	**3**
	(f)	$V_{10k} = 6 - 0.7 = 5.3\,V$	answer (unit not required)	1	
		$I_b = \frac{V}{R} = \frac{5.3}{10 \times 10^3}$			
		= 0·53 mA	answer (unit not required)	1	
		$h_{FE} = \frac{I_c}{I_b} = \frac{100 \times 10^{-3}}{530 \times 10^{-6}}$	substitutions	1	
		= 187	answer (must be no unit)	1	**4**
					(40)

Question			Mark Allocation			Marks	
10.	**(a)**		(holding) torque			1	
			accurate (angular) positioning; easily controlled by microcontroller			1	
			(any 2 acceptable answers)				**2**
	(b)	(i)	locate:	if pin 1 = 0 then locate	inc label	1	
			loop:	if pin 0 = 0 then loop	inc label	1	
				gosub pulsedata		1	
				b5 = DATA		1	
				pause 500		1	
				gosub pulsedata		1	
				if DATA = b5 then onward (OR b5 = DATA)		1	
				goto error		1	
			onward:	gosub pulsedata			
				b6 = DATA			
				pause 500	Repeated block of code	1	
				gosub pulsedata			
				if DATA = b6 then onagain (OR b6 = DATA)		1	
				goto error		1	
			onagain:	high 4	inc label	1	
				gosub x-move		1	
				high 6		1	
				gosub y-move		1	
			ending:	return	inc label	1	
			error:	high 2	inc label	1	
				goto ending		1	**18**
		(ii)	xmove:	for count = 1 to b5 (OR DATA)	correct variable	1	
				high 5			
				pause 10			
				low 5	high & low	1	
				pause 10	both pauses	1	
				next count	counting loop	1	
				return		1	**5**
	(c)		• The variable-resistor-voltage-divider sets light level required to switch comparator output.			1	
			• LDR produces increasing voltage signal as light level decreases.			1	
			• When picker not breaking light beam comparator output is 0 V. When light beam broken comparator output goes high.			1	
			• Voltage to microcontroller conditioned (by resistors)			1	**4**

Question			Mark Allocation		Marks	
	(d)		85% of 12 V = 10·2 V	saturation value	1	
			$\frac{R}{2} = \frac{5}{5 \cdot 2}$	expression and substitution	1	
			R = 1·92 kΩ	answer	1	**3**
	(e)	(i)	$\frac{R_2}{6} = \frac{4}{5}$	substitutions	1	
			R_2 = 4·8 kΩ	answer	1	
			$\frac{R_1}{6 + 4 \cdot 8} = \frac{3}{9}$	substitutions	1	
			R_1 = 3·6 kΩ	answer	1	**4**
		(ii)	'Dark' signal changes state when $V_{in} = V_{ref}$ = 9 V		1	
			$\frac{R_{LDR}}{5} = \frac{9}{3}$	substitutions	1	
			$R_{LDR} = \frac{9}{3} \times 5 = 15\,k\Omega$	answer	1	
			Light level for 15 kΩ = 5 lux (accept 5–6 lux)	answer	1	**4**
						(40)

Question			Mark Allocation		Marks	
11.	**(a)**		Thermocouple generates a voltage signal dependent on temperature. Thermistor is resistive so requires power supply and voltage divider.		1 1	**2**
	(b)		thermocouple 1: 400 ºC = 16 mV thermocouple 2: 100 ºC = 4 mV	2 values	1	
			$T_1 : -\frac{R_f}{R_i} = -\frac{18}{200} = -0{\cdot}09 \times 16 = -1{\cdot}44\,\text{mV}$		1	
			V_1 to diff. amp $= -1.44 \times (-1)$ = 1.44 mV	answer	1	
			$T_2 : 1 + \frac{R_f}{R_i} = 1 + \frac{270}{100} = 3.7$	substitutions	1	
			V_2 to diff. amp $= 3.7 \times 4$ = 14.8 mV	answer	1	
			difference at inputs $= 14.8 - 1.44 = 13.36\,\text{mV}$		1	
			V_{out} = 3.84 V $A_V = \frac{V_{out}}{V_{in}} = \frac{3.84}{13.36 \times 10^{-3}}$	substitutions	1	
			= 287.5	answer no unit	1	
			$A_V = \frac{R_f}{R_i} \Rightarrow R_i = \frac{R_f}{A_v}$ $= \frac{820 \times 10^3}{287.5}$	substitutions	1	
			R_i = 2.85 kΩ	answer	1	**10**
	(c)	(i)	Threshold voltage = 3.82 V $(3{\cdot}80 \le V_T \le 3{\cdot}82$ V)	within range	1	
			I_{sat}=40.8 mA	value	1	**2**
		(ii)		offset from origin correct curve shape saturation line axis labels	1 1 1 1	**4**
		(iii)	$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$ $= \frac{10.2}{0.04}$	substitutions	1	
			= 255	answer (no unit)	1	**2**

Question		Mark Allocation		Marks	
	(d)		+/-power rails npn correct pnp correct motor with connections	1 1 1 1	**4**
	(e)	$\Sigma M_{pivot} = 0\ (\overset{\frown}{+ve})$			
		$-(900\cos 20\times 1.6)+(720\sin 8\times 1.2)+(F\sin 77\times 0.3)=0$	3 terms	3	
		$F=\dfrac{(900\cos 20\times 1.6)+(720\sin 8\times 1.2)}{0.3\sin 77}$	manipulation	1	
		$F = 4218\text{ N} = 4{\cdot}22\text{ kN}$	answer	1	**5**
	(f)	$\Sigma F_V = 0(\uparrow +ve)$			
		$-900\cos 20+720\sin 8-4218\sin 77+R_V=0$	3 correct terms	3	
		$R_V = 845.7 - 100.2 + 4110$			
		$R_V = 4855\text{ N}\uparrow$	answer	1	
		$\Sigma F_h = 0(\overset{\rightarrow}{+ve})$			
		$-900\sin 20+720\cos 8-4218\cos 77+R_h=0$	3 correct terms	3	
		$R_h = 308 - 713 + 949$			
		$R_h = 544\text{ N}\rightarrow$	answer	1	
		 $R_P=\sqrt{4855^2+544^2}$		1	
		$R_p = 4885\text{ N}$	answer and unit	1	
		$\theta=\tan^{-1}\left(\dfrac{4855}{544}\right)=83{\cdot}6°$ $6{\cdot}4°$		1	**11**
					(40)

[END OF MARKING INSTRUCTIONS]