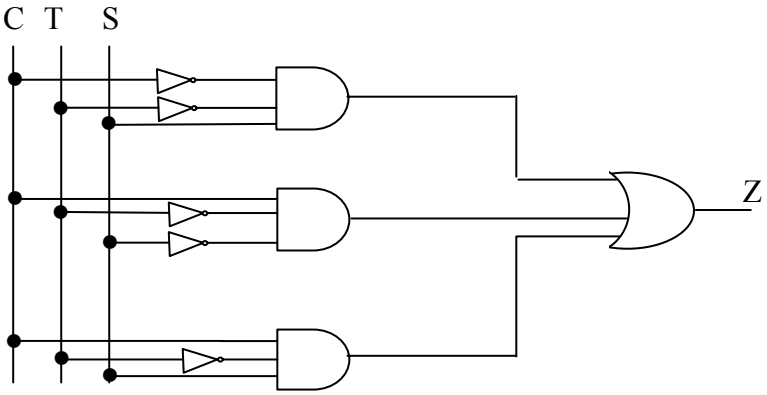
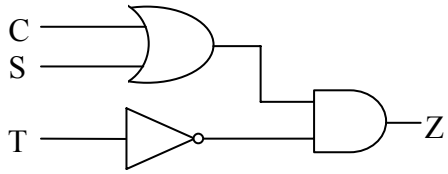
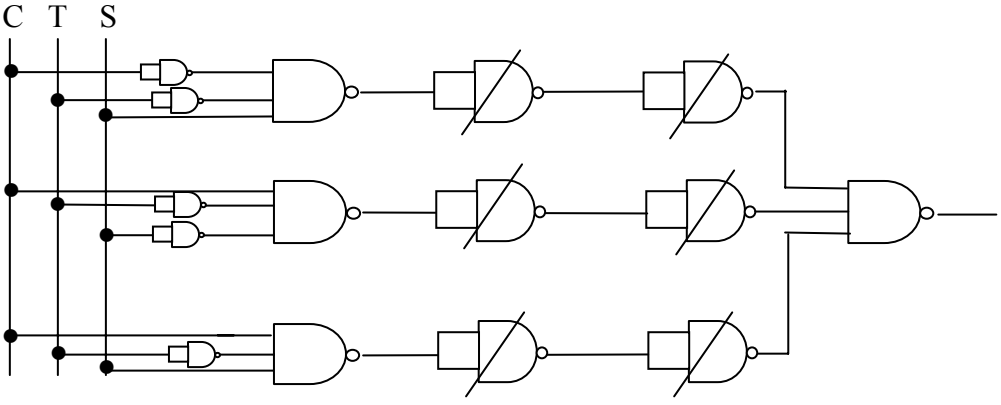
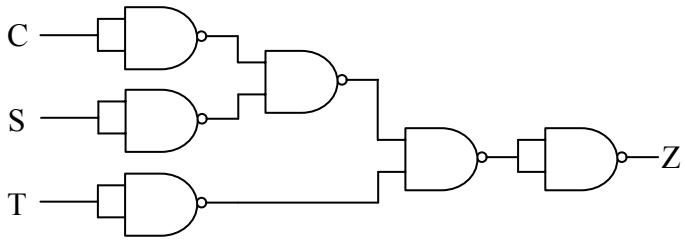
2009 Technological Studies

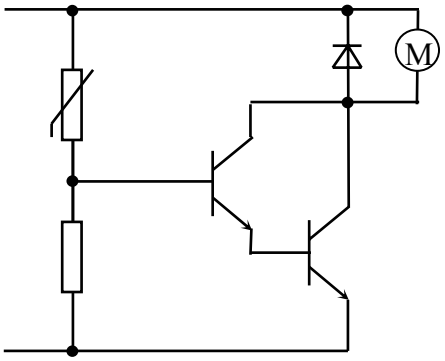
Higher

Finalised Marking Instructions

Section A

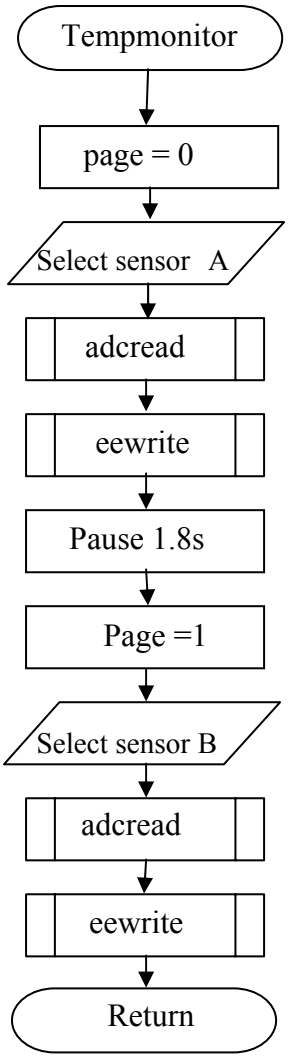
Question		Mark Allocation		Marks	
1.	**(a)**	$Z = (\overline{C}.\overline{T}.S) + (C.\overline{T}.\overline{S}) + (C.\overline{T}.S)$	½ mark for each item in brackets ½ for linking with OR function	1½ ½	**2**
		OR			
		$Z = \overline{T} . (C + S)$	(C + S) function $\overline{T}$. function	1 1	**2**
	(b)				
		Also can be implemented with just three NOT gates	NOT gates Correct input connection to NOT gates ½ for each AND gate and its input connections OR gate	½ ½ 1½ ½	**3**
		OR			
			OR gate and correct inputs NOT gate and correct inputs AND gate and correct inputs	1 1 1	**3**
	(c)				
			NOT equivalents and correct input connections AND equivalents and correct input connections OR equivalent and correct input connections Cancellation of redundant gates	½ ½ ½ ½	**2**

Question		*Mark Allocation*	*Marks*	
		OR  		
		OR equivalent and correct input connections	1	
		NOT equivalent and correct input connections	½	
		AND equivalent and correct input connections	½	**2**
	(d)	(i) CMOS no ½ marks	1	
		(ii) Voltage range suitable for 9V supply.	½	
		Low current usage/low power consumption	½	**2**
		Fan out		
		Noise immunity NOT cost		
				(9)

Question		Mark Allocation	Marks	
2.	**(a)**	A diode	½	
		The diode prevents back emfs from damaging the transistor. (Full answer required)	½	**1**
	(b)	*Input sub-system:*		
		- The input sub-system consists of a thermistor and resistor in a voltage divider.		
		- As the temperature rises, the resistance of the thermistor falls.		
		- As the temperature rises, the voltage across the thermistor falls.		
		any two answers: (½)	1	
		As the temperature rises the signal voltage rises (or the voltage at the base of the transistor rises). (½)	½	
		Process sub-system:		
		- When the voltage on the base of the transistor reaches 0.7 V a base current flows.		
		- The transistor amplifies the base current into a larger collector current.		
		- When the voltage on the base of the transistor reaches 0.7 V the transistor is switched on.		
		- When the transistor is switched on collector current flows.		
		any two answers @ ½ mark each:	1	
		Output sub-system:		
		- When current flows through the motor (or transistor switches on) the motor turns.		
		½ mark:	½	**3**
	(c)	(i)		
				
		correct Darlington pair arrangement (½)		
		correct connections shown or indicated to rest	1	
		of circuit (½)	1	
		(ii) Darlington pair/Darlington driver.		
		(iii) $h_{FE(overall)} = h_{FE\ (1)} \times h_{FE\ (2)}$		
		$h_{FE\ (2)} = h_{FE(overall)} \div h_{FE\ (1)}$ formula, stated or implicit (½)		
		$h_{FE\ (2)} = 1500 \div 50 = 30$ answer with no units (½)	1	**3**
	(d)	A MOSFET transistor is *voltage operated*, whereas a bipolar transistor is *current operated.*		**1**
				(8)

Question		*Mark Allocation*		*Marks*	
3.	**(a)**	(i) 12 x 4 x 7.5 = 360^0	no half marks (unit not required)	1	
		(ii) 12 x 4 x 20 = 960 ms (0.96 s)	no half marks (units required)	1	**2**
	(b)	main: let dirs = %11110000 (optional) for b0 = 1 to 24 let pins = %01100000 pause 5 let pins = %01010000 pause 5 let pins = %10010000 pause 5 let pins = %10100000 pause 5 next b0 end			
			correct time delays	½	
			correct number of loops	½	
			steps in correct order	1	**2**
	(c)	Only two output pins of the microcontroller are required.		1	
		The programming is simpler/easier to change.		1	**2** **(6)**

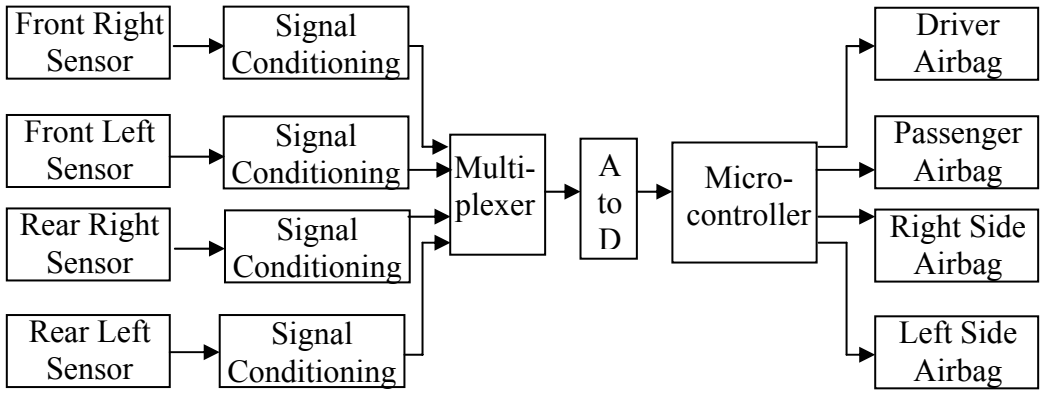
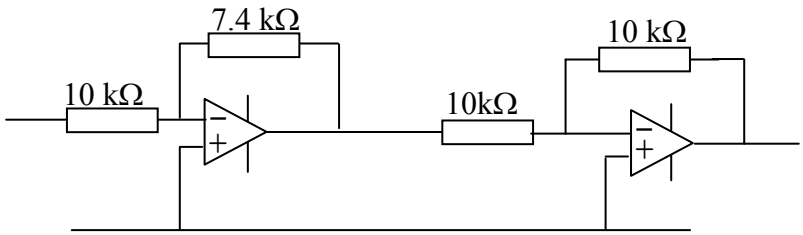
Question		Mark Allocation		Marks
4.	**(a)**	Ductile.		**1**
	(b)	$\sigma = F/A$		
		$= 30/80$ correct substitution of values using a load value within elastic region	½	
		$= 0.375$ kN/mm^2 correct calculation (units not necessary)	½	
		$\varepsilon = \Delta l/l$		
		$= 0.1/50$ correct substitution of values using the corresponding extension value	½	
		$= 0.002$ correct calculation	½	
		$E = \sigma/\varepsilon$		
		$= 0.375/0.002$ correct substitution into correct formula	½	
		$= 188$ kN/mm^2 correct answer including correct units	½	**3**
	(c)	$\sigma_{ultimate} = F/A$		
		$= 80/80$ correct substitution into correct formula	½	
		$= 1$ kN/mm^2 correct answer including correct units	½	**1**
	(d)	(i) Factor of Safety $= \sigma_{ultimate} / \sigma_{safe\ working}$		
		$\sigma_{safe\ working} = \sigma_{ultimate}$ / Factor of Safety		
		$= 1000$ N/mm$^2/6$ correct substitution into correct formula	½	
		$= 167$ N/mm^2 correct answer including correct units	½	**1**
		(ii) $\sigma = F/A$		
		$F = \sigma \times A$		
		$= 167 \times 30 \times 10$ correct substitution into correct formula	½	
		$= 50.1$ kN correct answer including correct units	½	**1**
				(7)

Question		Mark Allocation	Marks	
5	**(a)**	A multiplexer allows either of the analogue signals to be selected; or A multiplexer enables more than one analogue sensor to be connected to one A to D converter.		**1**
	(b)			
		tempmonitor & return boxes all other box content ½ mark each correct box types (subtract ½ for first instance of incorrect box type up to 1 mark maximum)	½ 4 ½ 1	**6** **(7)**

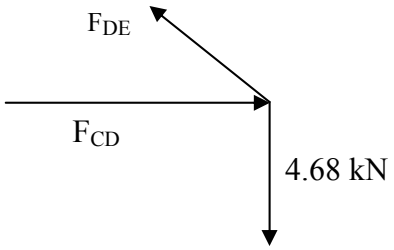
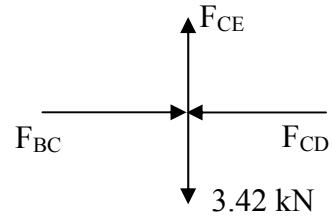
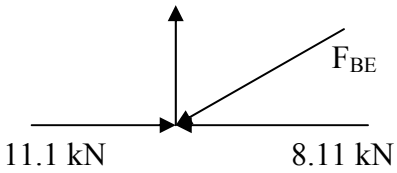
Question		Mark Allocation		Marks	
6.	**(a)**	LDR resistance = 200Ω	from data book	½	
		Rv = 200/1000 x 8	substitution	½	
		= 1.6 kΩ	answer ½; units ½	1	**2**
	(b)	Maximum output voltage before saturation = 85% of 9V = 7.65V	calculation	½	
		I = V/R	formula stated or implied	½	
		= (7.65 – 0.7)/ 760	substitution	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)

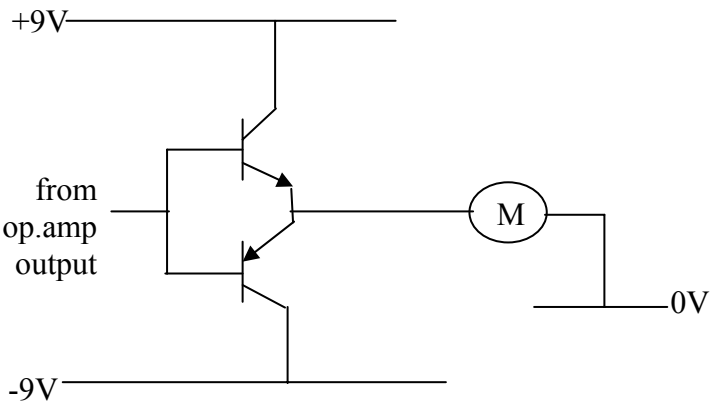
Question		*Mark Allocation*	*Marks*	
8.	**(a)**	Digital to analogue converter (summing amplifier and inverting amplifier - ½ mark)		**1**
	(b)	$V_{out} = -R_f (V_1/R_1 + V_2/R_2 + V_3/R_3 + V_4/R_4) \times -R_f/R_i$ (½ for whole formula, stated or implicit)	½	
		$V_{out} = -100 (0/800 + 5/400 + 0/200 + 5/100) \times -100/100$ correct substitution (½ for 1 mistake, 0 for more than 1 mistake)	1	
		$V_{out} = 6.25$ V answer, including units	½	**2**
	(c)	Pulse width modulation (pwm - ½ mark)		**1**
	(d)	3:1		**1**
	(e)	(i) The motor would gradually (or gently) accelerate to full speed. (accelerate - ½ mark; gradually or gently - ½)	1	
		(ii) The purpose is to avoid damage to the motor (or mechanisms connected to the motor). To reduce wear in components.	1	**2**
				(7)

Section B

Question		Mark Allocation		Marks
9.	**(a)**			
		All four sensors	½	
		Four signal conditioning sub-systems	½	
		Multiplexer	½	
		A to D	½	
		Microcontroller	½	
		All four airbag outputs	½	**3**
	(b)	Av = 5/6.8 = 0.74 — Voltage gain calculation	½	
		Two inverting amplifiers.	½	
		First amplifier, Rf = 7.4 kΩ, Ri=10 k Ω (or any other pair in kΩ range)	½	
		Correct connections and resistors correct way round	½	
		Second amplifier, Rf = 10 kΩ, Ri=10 kΩ (or any other pair in kΩ range)	½	
		Correct connections and resistors correct way round	½	
		Not in kΩ range – deduct ½ mark once only		**3**
				

Question		Mark Allocation		Marks	
	(c)	10110111 = 183	calculation	½	
		Vin to ADC = 5 x 183/255 = 3.59V	calculation	½	
		V from sensor = 3.59/0.74	calculation	½	
		= 4.88 V	answer (including units)	½	**2**
		<u>Alternative answer</u>			
		V from sensor = 6.8 x 183/255	calculation	1	
		= 4.88 V	answer ½, units ½	1	**2**
	(d)	frontbags: low 0	(½)		
		gosub adcread	(½)		
		if data > 147 then testpassenger	(1)		
		testdriver: high 0	(½)		
		gosub adcread	(½)		
		if data > 103 then deploydrivers	(1)		
		return	(½)		
		testpassenger: if data > 182 then deployboth	(1)		
		high 6	(½)		
		goto testdriver	(½)		
		deployboth: high6 } high7 }	(½)		
		return	(½ both returns)		
		deploydrivers: if data > 182 then deployboth	(1)		
		high7	(½)		
		return	no marks for labels		**9**
	(e)	$V_{out} = - R_f(V_1/R_1 + V_2/R_2 + V_3/R_3 + V_4/R_4)$	formula, stated or implicit	½	
		$- 4.5 = -R_f (1.2/10 + 1.2/10 + 0.6/5 + 0.6/5)$	correct substitution	½	
		$- 4.5 = -R_f (4.8 \times 10^{-4})$	calculation	½	
		$R_f = 9.38\ k\Omega$	answer including units	½	**2**
	(f)	$I_c = 3.6/6 = 0.6$ A			
		$h_{FE} = 600/15.5$	calculation	½	
		= 38.7	answer	½	**1**
					(20)

Question		Mark Allocation		Marks	
10.	**(a)**	Analysing Node D			
			$\Sigma F_{up} = \Sigma F_{down}$ $F_{DE}\cos 60 = 4.68$ 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	
		Analysing Node C			
			$\Sigma F_{left} = \Sigma F_{right}$ $F_{BC} = F_{CD}$ $F_{BC} = 8.11$ kN (compression) magnitude & units & nature	 1	
		Analysing Node B			
			$\Sigma F_{left} = \Sigma F_{right}$ $F_{BE}\cos 30 + 8.11 = 11.1$ 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**

Question	Mark Allocation		Marks	
(c)				
		NPN/PNP transistors (½ mark each)	1	
		transistor connections	½	
		motor	½	**2**
(d)	(i) $V_2-V_1 = V_{out}/(R_f/R_i)$	formula, stated or implicit	½	
	$V_2-V_1 = 9.68/(260/9)$			
	$V_2-V_1 = 0.34$	answer (units not necessary)	½	
	$V_1 = V_2-0.34$			
	$V_1 = 4.08 - 0.34$	calculation	½	
	$V_1 = 3.74$ V	answer including units	½	**2**
	(ii) V_{out} (max) = 0.85 x 16 = 13.6 V	calculation and answer	½	
	$V_2-V_1 = 13.6/(260/9) = 0.47$ V	calculation and answer	½	**1**
(e)	If lower resistance in potentiometer B is increased/altered, V_2 will increase/change Non-inverting input voltage becomes greater than inverting input voltage Difference amplifier amplifies voltage difference, output goes positive & motor turns As motor turns lower resistance of potentiometer A increases and V_1 increases Voltage difference decreases and motor slows and then stops. If lower resistance of potentiometer B is decreased then motor will turn other way V_1 will decrease and the motor will slow down and stop			
		any four answers (½ mark each)		**2**
(f)	Increase gain of difference amplifier			**1**
(g)	Motor will overshoot desired position. Motor will not settle at desired position (it will hunt). Motor will run either full speed forward or full speed reverse ON/OFF NOT acceptable			
		any answer		**1**
				(20)

Question		Mark Allocation		Marks
11	**(a)**	(i)		

X	Y	Z
0	0	0
0	1	0
1	0	1
1	1	0

(no half marks) **1**

(ii) $Z = X \cdot \overline{Y}$ (no half marks) **1**

(b) Keys 4, 6 and 7 must be pressed (no half marks) **1**

(c) The correct keys must be held down to open the door. (no half marks) 1
If any of the correct keys are released, the door will shut. (no half marks) 1 **2**

(d) (i) 4, 5, 6 and 7 (no half marks) **1**
(ii) Input pin 2 **1**

(e)

main:	gosub scan	½ for all three 'gosub scan' commands
	if b0 = 10 then scan2	1
	goto main	½
scan2:	gosub scan	(awarded above)
	if b0 = 12 then scan3	1
	goto scan2	½
scan3:	gosub scan	(awarded above)
	if b0 = 12 then scan 3	1
	if b0 = 3 then scan 4	1
	goto main	½ **6**

(f) The # key must be pressed, then released; the '3' key must be pressed, then released; the '8' key must be pressed, then released; the '5' key must be pressed, then released.
key ½
correct number keys in correct order 1
pressing then releasing of each key ½ **2**

(g) $R = V/I = (5 - 0.7)\ V/0.8 \times 10^{-3}$ (correct substitution in correct formula) ½
$= 5.38\ k\Omega$ (correct answer including units) ½ **1**

(h) The microcontroller signal is low ½
The NPN transistor is switched off ½
the voltage at the collector of the transistor is +12 V ½
this voltage is applied to the gate of the MOSFET, turning red LED on ½ **2**

(i) Current through solenoid = V/R = (12 - 0.2)/50 = 0.236 A (units not necessary) 1
Total collector current = 0.236 + 0.020 = 0.256 (only 1 LED is on)
(units not necessary) ½
h_{FE} = Ic/Ib = 256/0.8 = 320 (**NO** units) ½ **2**
(20)

[END OF MARKING INSTRUCTIONS]