[C036/SQP142]

Higher Technological Studies

Specimen Question Paper

Time: 3 hours

NATIONAL QUALIFICATIONS

100 marks are allocated to this paper.

Answer **all** questions in Section A (60 marks).

Answer **two** questions from Section B (20 marks each).

Where appropriate, you may use sketches to illustrate your answer.

Reference should be made to the Data Booklet (1999 edition).

SCOTTISH QUALIFICATIONS

SECTION A

Attempt all the questions in this Section. (Total 60 marks)

Marks

1. The stress/strain graphs for specimens of three common engineering materials, all of which have been tested to destruction, are shown in Figure Q1.

Each specimen was of identical shape and size.

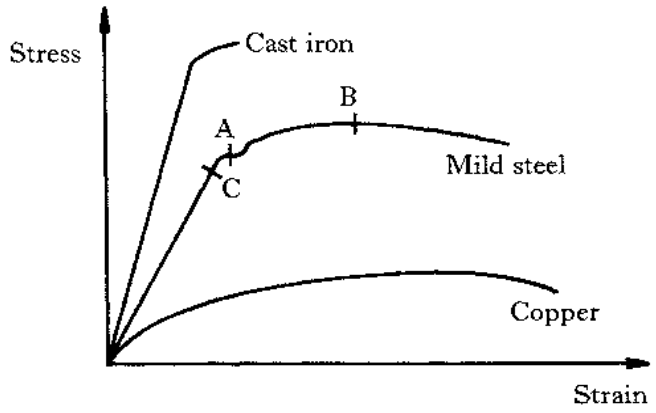

Figure Q1

(*a*) For the mild steel graph:

(i) name points A and B; **2**

(ii) name point C and explain what would happen to the specimen if it was loaded to a point between C and B. **2**

(*b*) Compare the materials in terms of:

ductility;
ultimate strength;
Young's modulus. **3**

(7)

2. (*a*) Name the configuration of amplifier shown in Figure Q2. **1**

(*b*) Calculate the gain of the amplifier. **1**

(*c*) (i) If the input signal V_i is 0·5 V, what is the value of the output signal V_0? **1**

(ii) Explain your answer. **1**

(4)

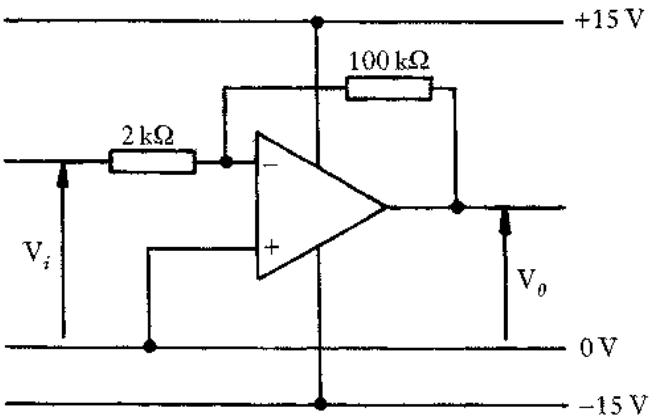

Figure Q2

Marks

3. Figure Q3 shows a frictionless pulley system which is used by a professional display team when flying large kites.

The wind force on the kite sets up a tension in the rope and the pulley arrangement settles into the position shown. If the angle between the link and the horizontal is 30 degrees, determine the tension set up in the rope.

The weight of the pulley is 60 N. Assume the **four** forces acting on the pulley are concurrent.

Ignore the weight of the rope and the weight of the link. **(6)**

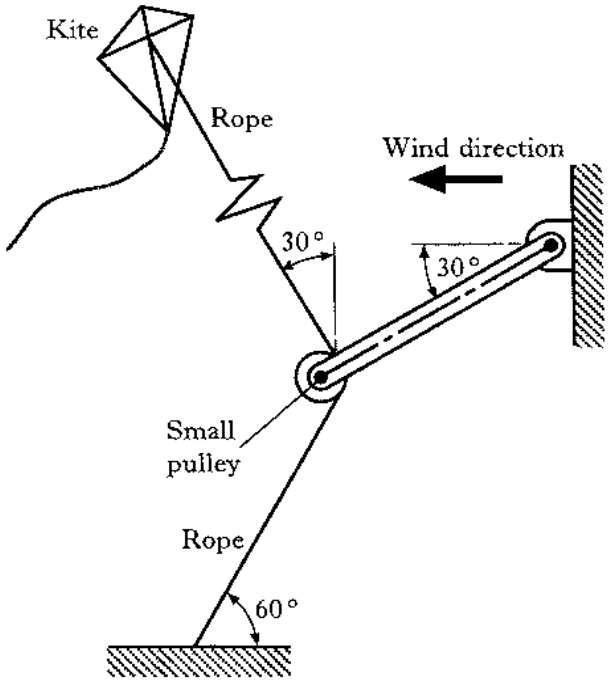

Figure Q3

Marks

4. A small d.c. motor, which is used to drive a model conveyor belt, is to be controlled using a microcontroller. The microcontroller gives out a 6 V signal when an output pin is switched to logic 1. The speed of the motor must be varied according to the loads which are to be carried. For convenience, the speed is to be reduced using pulse-width modulated control. Output connections to the microcontroller are as follows.

Input	Pin	Output
	0	..... *Motor Clockwise*
	1	..... *Motor Anti-clockwise*
	2	
	3	
	4	
	5	
	6	
	7	

Figure Q4

(*a*) Explain how pulse-width modulated control is used to vary the speed of the motor. **2**

(*b*) Develop a short procedure in PBASIC which could be used to drive the motor in a clockwise direction with a mark-to-space ratio of 2:1. **3**

(*c*) Explain how you would alter the control procedure in (*b*) to make the motor rotate in an anti-clockwise direction, with the same mark-to-space ratio. **1**

(6)

5. One side of a loaded structure is shown in Figure Q5. The structure is pin-jointed, with a hinge at point A and a roller support at B.

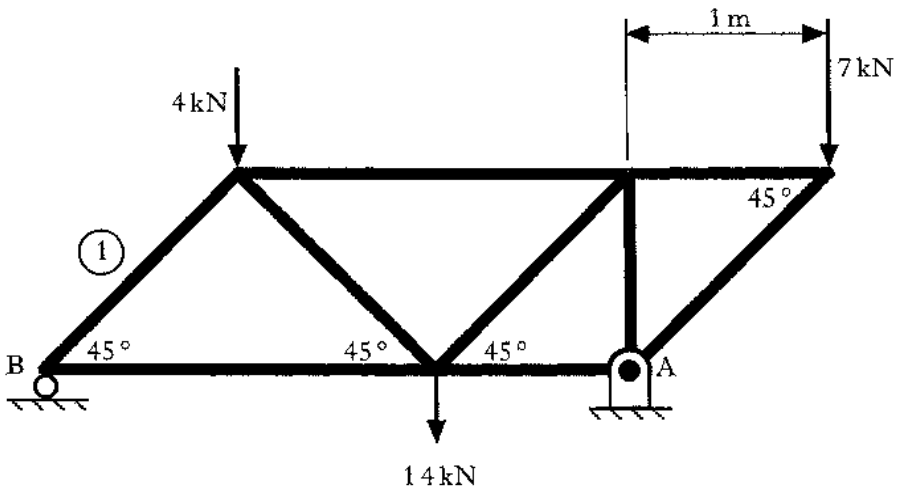

Figure Q5

(*a*) Calculate the magnitude of the roller reaction at B. **3**

(*b*) Determine the magnitude and nature of the force in member (1) by "nodal analysis". **4**

(7)

Marks

6. An electronic engineer constructs the circuit shown in Figure Q6 to test a temperature control system for a cooling fan.

At a temperature of 30 °C, she finds that the transistor is fully saturated with a base current of 500 μA.

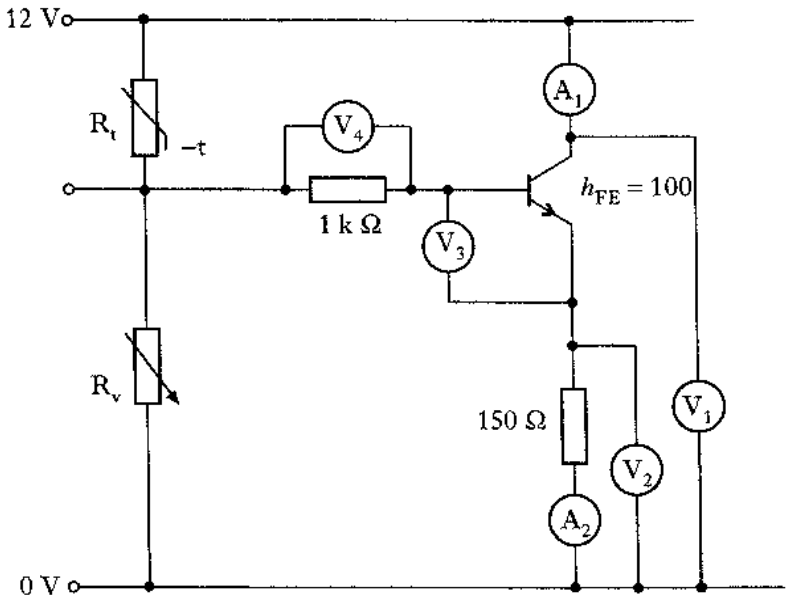

Figure Q6

(*a*) For this condition, determine:

(i) the reading on the two ammeters

A_1 and A_2; **2**

(ii) the reading on each of the four voltmeters

$V_1 - V_4$. **4**

(*b*) The thermistor used in the test circuit is a type 151–136.

(i) Determine the resistance of the thermistor when the transistor is fully saturated. **1**

(ii) Determine the voltage drop across the variable resistor R_v. **1**

(iii) Calculate a suitable value of R_v. **2**

(10)

7. (*a*) Explain why each of the following devices may be required in a microprocessor control system:

(i) A-D converter; **1**

(ii) multiplexer. **1**

(*b*) A microcontroller-based monitoring system is used to record and log data over a period of time. This is in the form of sound signals. It is found that the maximum voltage generated from the sound signals is 6 V. However, the maximum voltage which may be fed into the microcontroller system is 1·8 V.

(i) Draw a circuit diagram of a suitable signal conditioning system, based on operational amplifiers, which will allow the signals to be monitored without damaging the microcontroller. Indicate the values of any components used in your circuit. **5**

(ii) If the sound signal is fed into the microcontroller through an A-D converter which has a reference voltage of 1·8 V, write down the 8-bit binary pattern you would expect from the A-D converter when the sound signal generates a voltage of 4·8 V.

Clearly identify the least significant bit (LSB). **3**

(10)

Marks

8. A logic diagram is shown in Figure Q8.

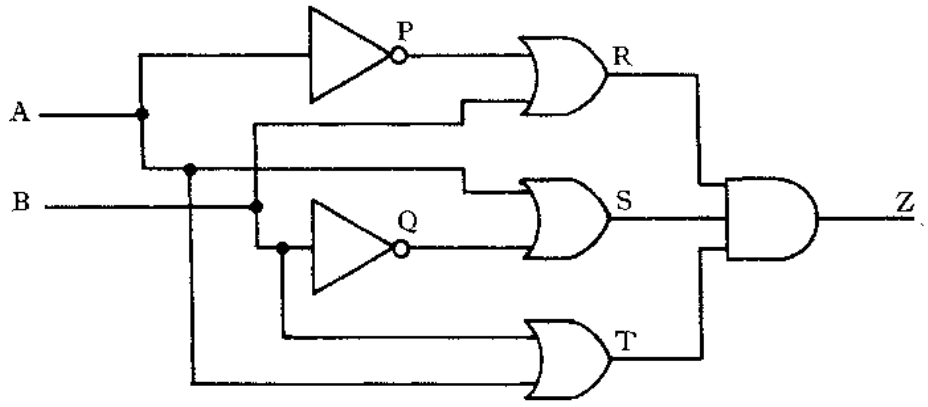

Figure Q8

(*a*) State **two** characteristics of the CMOS logic IC family. **1**

(*b*) Draw up a truth table for this logic system and hence write a Boolean logic statement for the output Z, in terms of the two inputs A and B. **7**

(*c*) Draw a simplified logic diagram, using only NAND gates, which will operate in exactly the same way as the logic gates shown in Figure Q8. **2**

(10)

[END OF SECTION A]

SECTION B

Attempt any TWO questions in this Section. Each question is worth 20 marks.

Marks

9. Load/extension tests were carried out on two different materials (A and B). The readings were fed into a computer and a listing of stress/strain readings was obtained as shown below.

Specimen A		*Specimen B*	
Stress (N/mm^2)	Strain ($\times 10^{-3}$)	Stress (N/mm^2)	Strain ($\times 10^{-3}$)
100	2·85	100	4·75
200	5·71	200	9·4
300	8·57	300	14·11
350 (yield pt)	10	425 (yield pt)	20
370 (UTS)	12·75	440 (UTS)	22·5

(*a*) **On the Worksheet Q9**, plot each stress/strain graph and then compare the results in terms of their Ultimate Tensile Stress, Ductility and Young's Modulus of Elasticity. **6**

(*b*) Part of a pneumatic system is shown in Figure Q9. Compressed air is stored in the tank at a maximum pressure of 8 N/mm^2 and the 120 mm diameter outlet is sealed by means of a valve block which is held in place using 15 mm (M15) diameter bolts as shown. The normal stress set up in each bolt due to tightening is 6 N/mm^2. The factor of safety for the system is 5.

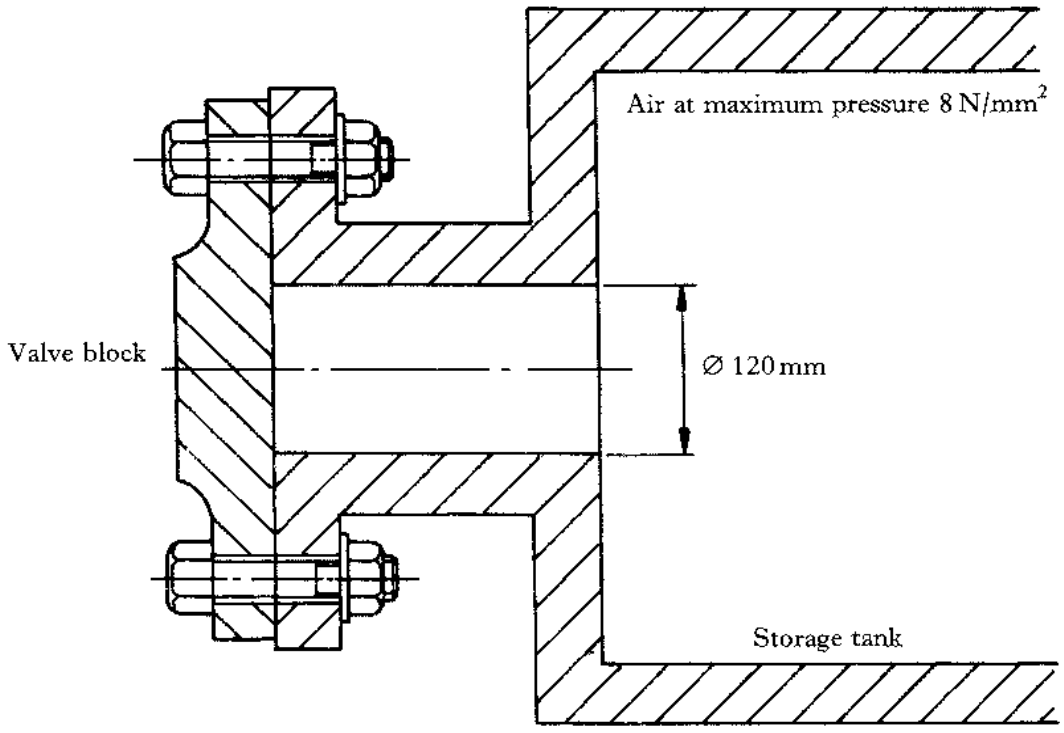

Figure Q9

(i) From the test in part (*a*), it has been decided that material A should be used for the bolts in this system. State one reason for this selection. **1**

(ii) Calculate the force exerted on the valve block due to the compressed air pressure. **3**

(iii) Determine how many bolts are required to attach the valve block to the storage tank. **10**

(20)

Marks

10. Figure Q10A shows the layout of a pulping machine used in a paper mill.

A batch, consisting of bales of wood pulp and bags of filler, is mixed with controlled volumes of water during the pulping process.

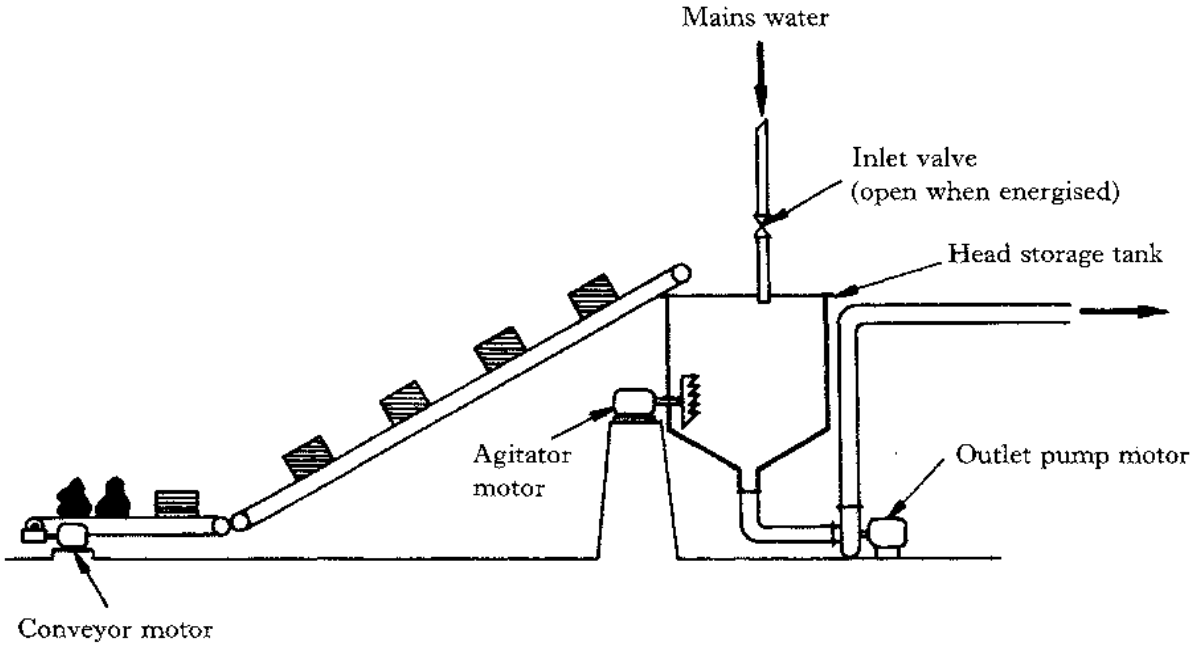

Figure Q10A

The microcontroller connections are shown in Figure Q10B. The inlet solenoid valve is open when energised.

Input	Pin	Output
Start switch	0	
	1	
	2	
	3	
	4	Inlet solenoid valve
	5	Conveyor motor
	6	Outlet pump motor
	7	Agitator motor

Figure Q10B

10. (continued)

PROCESS INFORMATION

Event	*Operation Action*	*Control Activity*
1.	Load conveyor with batch.	
2.	Press start button.	Sequence commences.
3.		Open inlet value. Close valve after 10 minutes.
4.		1 minute after inlet valve opens, start agitator motor. Run agitator for 11 minutes.
5.		Start conveyor 2 minutes after inlet valve opens. Run conveyor for 3 minutes.
6.		1 minute after agitator motor stops, start outlet pump. Run outlet pump for 3 minutes.
7.		Reset and wait for next start command.

(*a*) Based on the instructions given in the "PROCESS INFORMATION" table, draw up a flow chart which shows the control sequence for the pulping sequence. **10**

(*b*) With reference to your flow chart, write a high level program in PBASIC to control the operation of the pulper.

Assume the use of a prewritten time delay sub-procedure "delay" which will produce a delay in multiples of one minute. The length of the delay is dependent on the value set in the variable "mins" before the sub-procedure is called. **10**

Example: **(20)**

Program structure	*Comment*
let mins = 5 call delay	produces a 5 minute delay

Marks

11. Figure Q11A shows the layout of a new audio mixing desk.

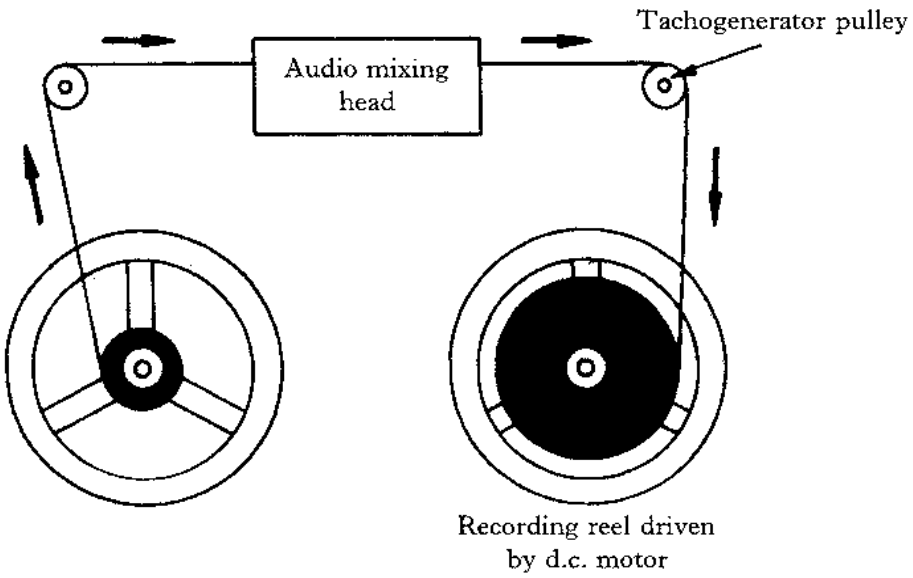

Figure Q11A

The tape is fed through the audio mixing head by being pulled on to a recording reel driven by a d.c. motor. As the tape builds up on the recording reel, the tape speed through the audio mixing head will increase.
To prevent this from happening, the d.c. motor is fitted to a closed loop control system.
A tachogenerator connected to a pulley senses the tape feed rate and sends an error signal to the control system.

(*a*) (i) Name the type of closed loop control used in this application. **1**

(ii) Name the amplifier used in this type of closed loop control. **1**

(iii) Draw a block diagram to represent the control system. **3**

(iv) Draw a circuit diagram of the control system and explain the function of each part of the circuit. **6**

Marks

11. (continued)

(*b*) The audio signals shown on the **Worksheet Q11** are mixed using the amplifier shown in Figure Q11B.

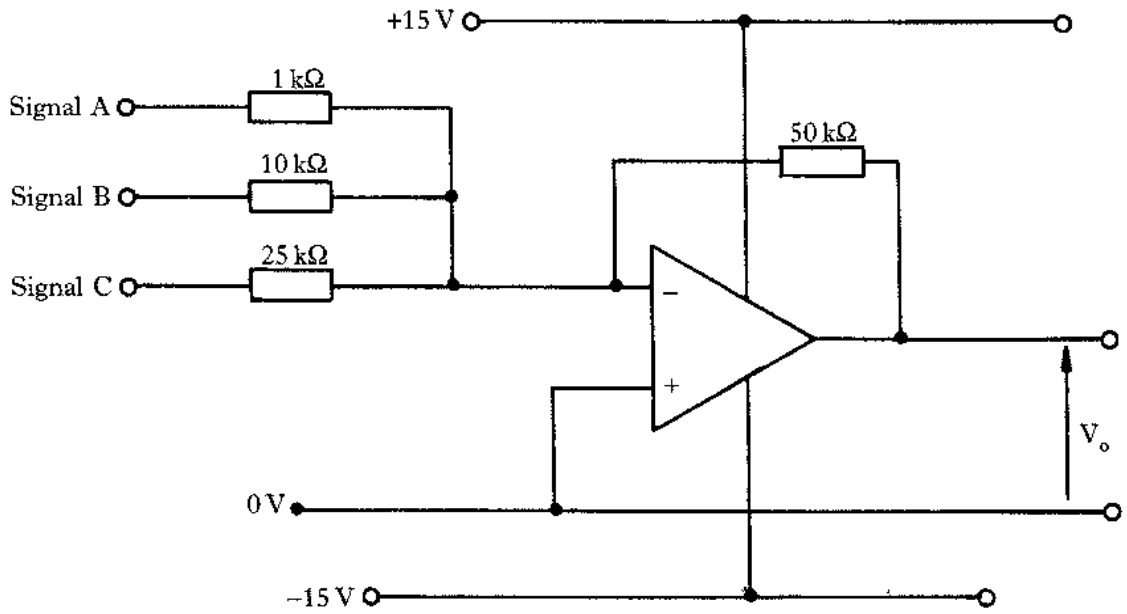

Figure Q11B

(i) Name the configuration of amplifier shown in the diagram Figure Q11B. **1**

(ii) **Refer to Worksheet Q11.** Calculate the maximum and minimum output voltages V_0 produced by the amplifier when the output is:

(1) signal A only; **1**

(2) signal B only; **1**

(3) signal C only. **1**

(iii) **On Worksheet Q11,** sketch the output wave form (V_0) produced by the amplifier when signals A, B, and C are input at the same time. **5**

(20)

[END OF QUESTION PAPER]

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Centre No.	Subject No.	Grade	Paper No.	Group No.	Marker's No.

[C036/SQP142]

Higher Technological Studies

Specimen Question Paper
Worksheet Q9 and Q11

Time: 3 hours

NATIONAL QUALIFICATIONS

Fill in these boxes and read what is printed below.

Full name of centre

Town

First name and initials

Surname

Date of birth
Day Month Year

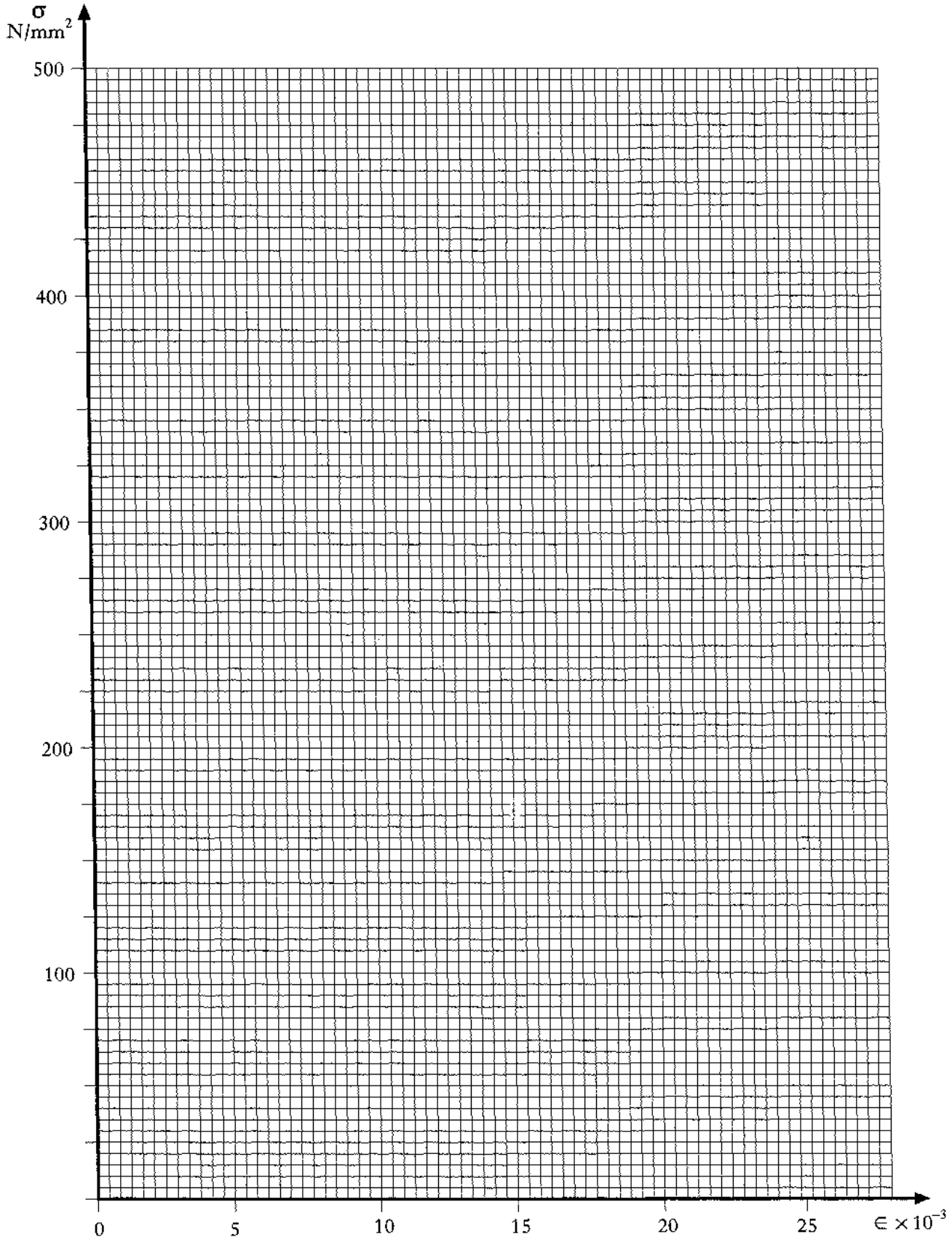
Candidate number

Number of seat

To be inserted inside the front cover of the candidate's answer book and returned with it ONLY by candidates who attempt Question 9 and/or Question 11.

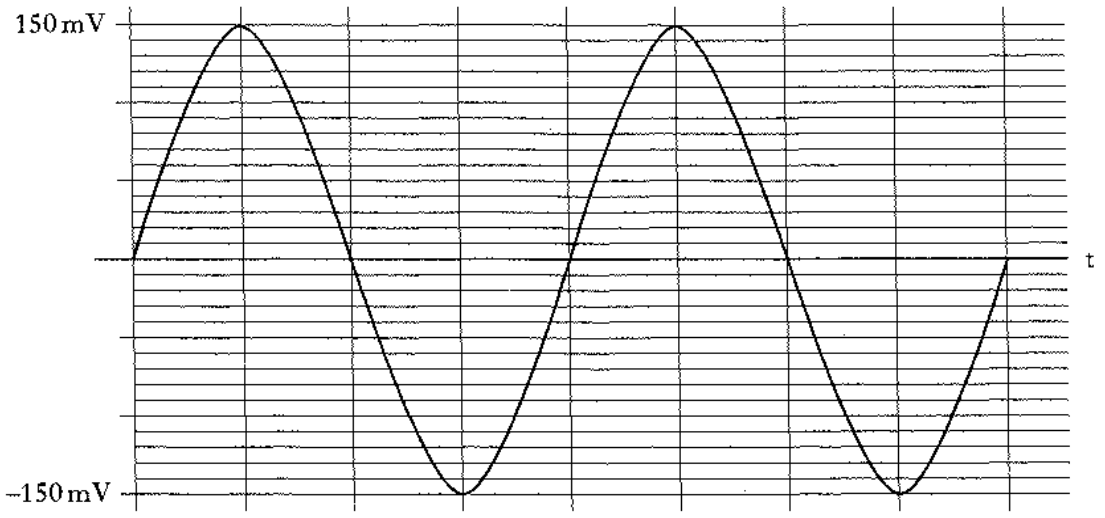
SCOTTISH QUALIFICATIONS

WORKSHEET Q9

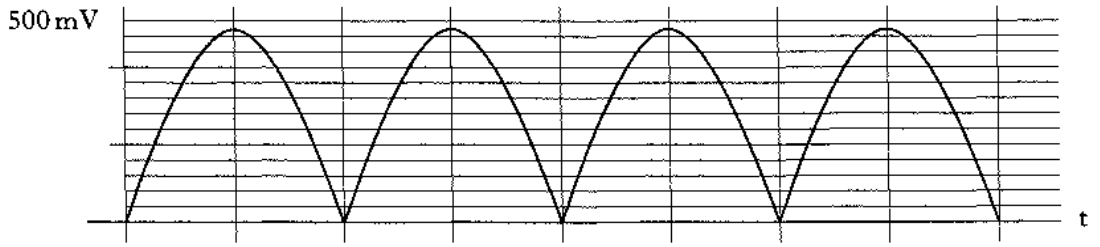


WORKSHEET Q11

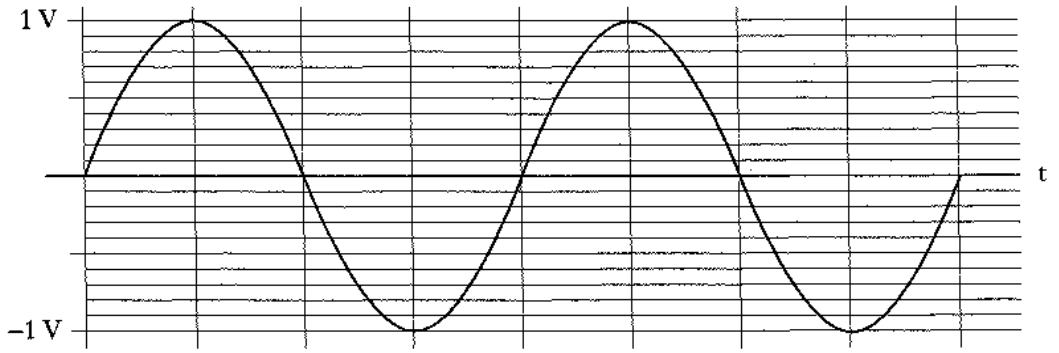
Input signal A



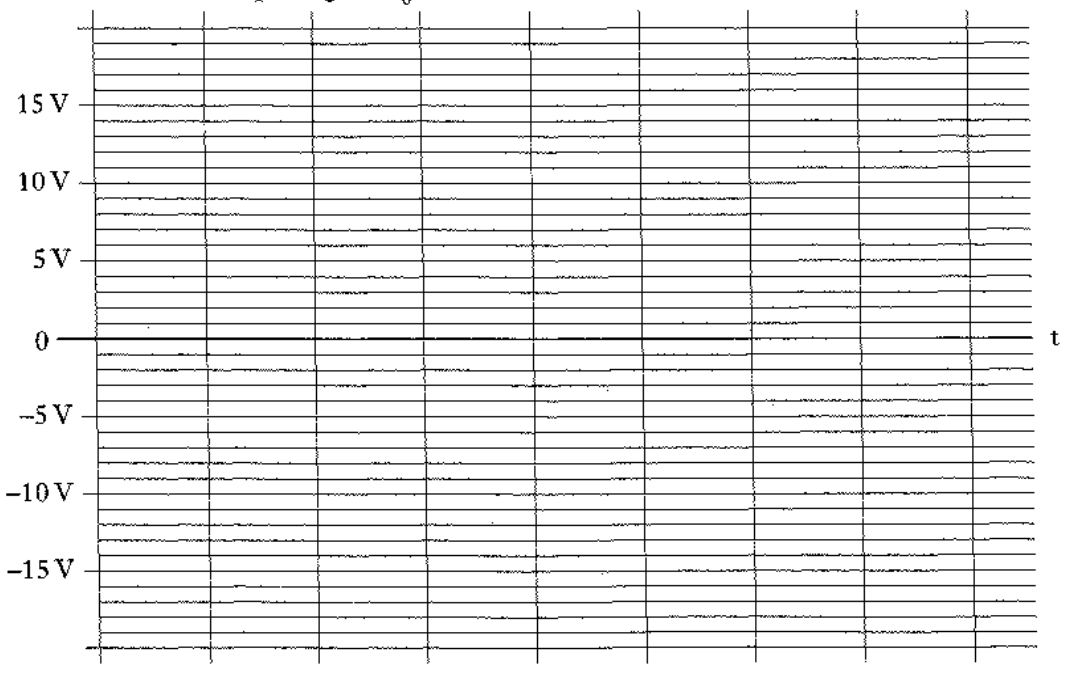
Input signal B



Input signal C



Output signal V_0



[C036/SQP142]

Higher Technological Studies

Specimen Marking Instructions

NATIONAL QUALIFICATIONS

SCOTTISH QUALIFICATIONS

				Marks
1.	(*a*)	(i) A = yield point;	1	
		B = ultimate (maximum) load.	1	2
		(ii) C = elastic limit.	1	
		If the specimen is loaded beyond C, it goes into the plastic range and any damage will be permanent.	1	2
	(*b*)	Copper is the most ductile material, cast iron the least ductile. Cast iron has the greatest ultimate strength.	1	
		Copper has the smallest ultimate strength.	1	
		Cast iron has the highest modulus, copper the smallest modulus.	1	3
				(7)
2.	(*a*)	Inverting amplifier.		1
	(*b*)	$A_v = -R_f/R_i = -100/2 = -50$.		1
	(*c*)	(i) Using $A_v = -50$, V_o should be $-50 \times 0{\cdot}5 = -25$ V. However, it will in fact be about −14 V.		1
		(ii) This is because the output from an op-amp saturates at ± 1 V less than the supply voltage being fed to it (which here is −15 V).		1
				(4)
3.	Solution			

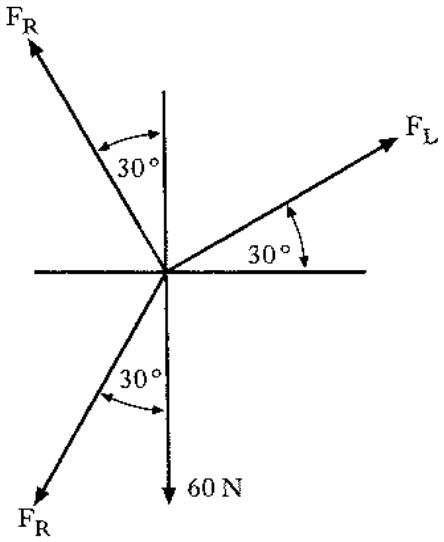


Diagram 1

$\sum F_y = 0$ 1

$F_L \cos 30 - F_R \cos 30 + F_L \sin 30 - 60 = 0$ ½

$F_L = \frac{60}{\sin 30}$ N ½

$\sum F_x = 0$ 1

$F_R \sin 30° + F_R \sin 30° - F_L \cos 30° = 0$ ½

$2F_R \sin 30° = 120 \cos 30°$ ½

$F_R = \frac{120 \cos 30°}{2 \sin 30°}$ N ½

$F_R = 103{\cdot}9$N ½

(to 3 significant figures 104N) **(6)**

			Marks
4.	(*a*)	The supply voltage to the motor is switched on and off at a high frequency.	1
		By varying the ratio of the on-time (mark) to the off-time (space) the speed of the motor can be altered.	1
			2
	(*b*)	simplest answer	

```
loop:       high 0        :  switch high        ½
            pause 2       :  mark time = 2      ½
            low 0         :  switch low         ½
            pause 1       :  space time = 1     ½
            goto loop     :  loop               1
```

preferable answer using symbols — 3

```
symbol dir = 0
symbol mark = 2
symbol space = 1

loop:       high dir      :  switch high
            pause mark    :  mark time = 2
            low dir       :  switch low
            pause space   :  space time = 1
            goto loop     :  loop
```

(*c*) Change the pin number from 0 to 1 in the high and low commands
or Change the pin number from 0 to 1 in the symbol "dir". — 1

(6)

5. (*a*)

$\sum M_A = 0$, therefore CWM = ACWM — ½

$(7 \times 1) + (3 \times R_B) = (14 \times 1) + (4 \times 2)$ — 1

$7 + 3R_B = 22$ — ½

$3R_B = 15$ — ½

$R_B = 5$ kN (acting vertically upwards). — ½ — 3

(*b*)

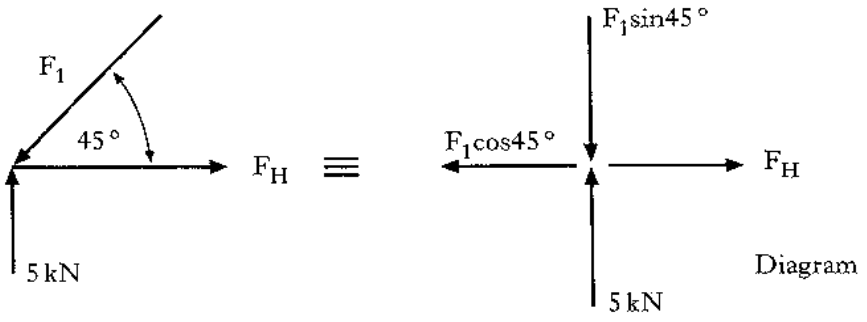


Diagram — 2

$\sum F_y = 0$ — ½

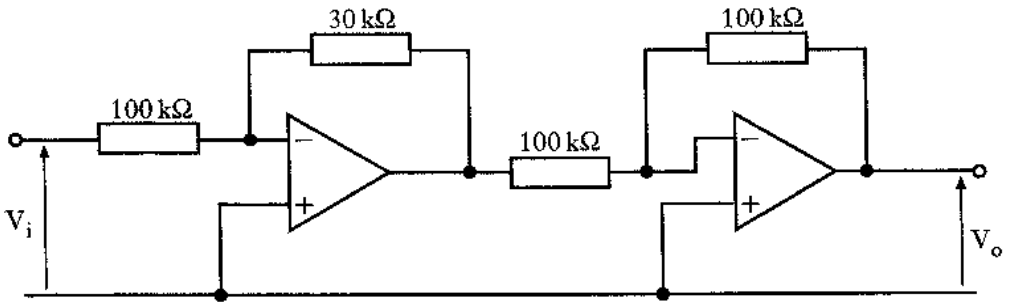
$F_1 \sin 45° - 5 = 0$ — ½

$F_1 = \frac{5}{\sin 45°}$ kN — ½

$= 7 \cdot 1$ kN — ½ — 4

					Marks
6.	(*a*)	(i)	$h_{FE} = \frac{I_c}{I_b}$		
			$I_c = h_{FE} I_b$		
			$I_c = 100 \times 500 \times 10^{-6}$ A		
			$= 50$ mA	**1**	
			$I_c = I_e = 50$ mA		
			$A_1 = A_2 = 50$ mA	**1**	**2**
		(ii)	By inspection		
			$V_1 = 12$ V	**½**	
			$V_3 = 0{\cdot}7$ V (accept range 0·6–0·7 V)	**½**	
			As $I_b = 500\,\mu$A		
			$V_4 = I_b R_b$		
			$= 500 \times 10^{-6} \times 10^3$ V		
			$= 0{\cdot}5$ V	**1½**	
			$V_2 = I_e R_e$		
			$= 50 \times 10^{-3} \times 150$ V		
			$= 7{\cdot}5$ V	**1½**	**4**
	(*b*)	(i)	From the data booklet at 30 °C		
			$R_t = 1$kΩ		**1**
		(ii)	Voltage drop across R_V		
			$V_v = V_4 + V_3 + V_2$		
			$= 0{\cdot}5 + 0{\cdot}7 + 7{\cdot}5$ V		
			$= 8{\cdot}7$ V		**1**
		(iii)	Voltage drop across R_t		
			$V_t = 12 - 8{\cdot}7$ V		
			$= 3{\cdot}3$ V	**1**	
			By proportion		
			$R_v = 1 \times \frac{8{\cdot}7}{3{\cdot}3}$ kΩ		
			$= 2{\cdot}64$ kΩ	**1**	**2**
					(10)

		Marks
7. (*a*) (i)	**A-D converter**: needed when analogue signals are being monitored by the microprocessor, because they can only accept digital signals.	1
(ii)	**Multiplexer**: needed when more than one input (analogue) is being monitored at the same time.	1
(*b*) (i)	$Av = \frac{V_o}{V_i} = \frac{1{\cdot}8}{6} = 0{\cdot}3$ (non-inverting).	1
	So, use (say) $R_f = 30\,k\Omega$ and $R_i = 100\,k\Omega$	1
	Diagram	3



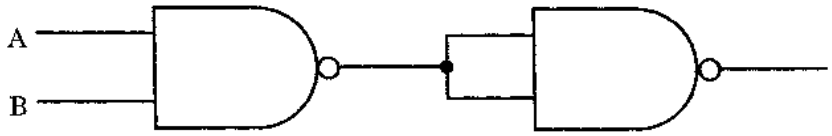
		5
(ii)	Sound signal in = 4·8 V, so V_{in} to A – D converter = $4{\cdot}8 \times 0{\cdot}3$	
	$= 1{\cdot}44$ V	1
	Now, ratio $\frac{V_o}{V_i} = \frac{x}{255}$, so $x = 204$ (this is the binary-coded decimal of the 8-bit pattern).	1
	Hence 8-bit pattern = 11001100 (LSB)	1
		3
		(10)

			Marks
8.	(*a*)	Any **two** correctly stated characteristics ie, operating voltage 3 – 15 V, noise immunity excellent.	**1**

(*b*)

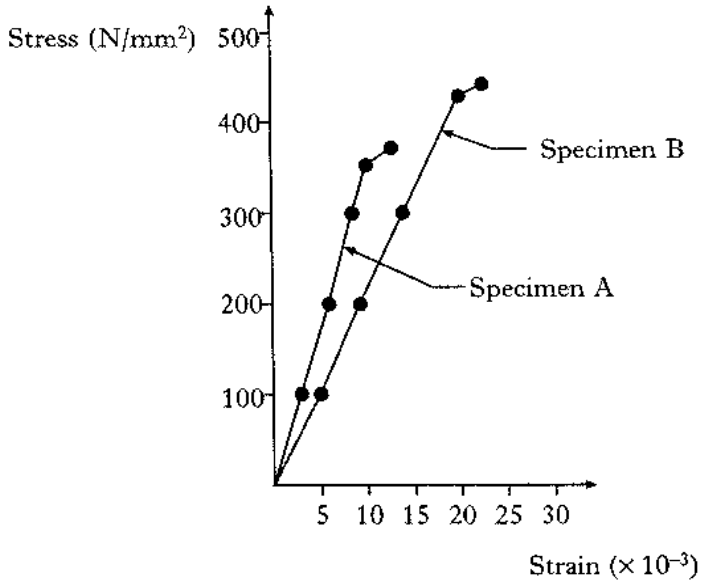
A	B	P	Q	R	S	T	Z		
0	0	1	1	1	1	0	0		
0	1	1	0	1	0	1	0	Hence Z = A.B	**1**
1	0	0	1	0	1	1	0	(1 mark for each column P to Z)	**6**
1	1	0	0	1	1	1	1		**7**

(*c*) AND from NANDs:



2

(10)

				Marks
9.	(*a*)		graphs (6 parts at ½ each) 3	
		Specimen B has a greater UTS than A.	1	
		Specimen B is more ductile than A.	1	
		Specimen A has a greater value of Young's Modulus of Elasticity than B.	1	6
	(*b*) (i)	Material A is more elastic—the bolts won't permanently elongate when loaded.		1
	(ii)	Force on valve block		
		$F_T = P \times A$	1	
		$F_T = 8 \times (\pi \times \frac{120^2}{4})$ kN	1	
		$= 90 \cdot 432$ kN	1	3
	(iii)	Safe working stress which can be carried by bolts.		
		$SWS = \frac{UTS}{F.O.S.}$	1	
		$SWS = \frac{370}{5}$ N/mm^2	½	
		$= 74$ N/mm^2	½	
		Stress due to tightening		
		$\sigma_t = 6$ N/mm^2	1	
		Stress available to support air loading per bolt.		
		$\sigma_\beta = SWS - \sigma_t$	1	
		$= 74 - 6$ N/mm^2	½	
		$\sigma_\beta = 68$ N/mm^2	½	

9. (continued)

Load which can be carried by each bolt (due to air).

$F_\beta = \sigma_\beta \times A$ **1**

$F_\beta = 68 \times (\frac{\pi \times 15^2}{4})\,N$ **½**

$F_\beta = 12\,kN$ **½**

Number of bolts required.

$N_\beta = F_T / F_\beta$ **1**

$= \frac{90{\cdot}4}{12}$ **½**

$= 7{\cdot}53$ bolts **½**

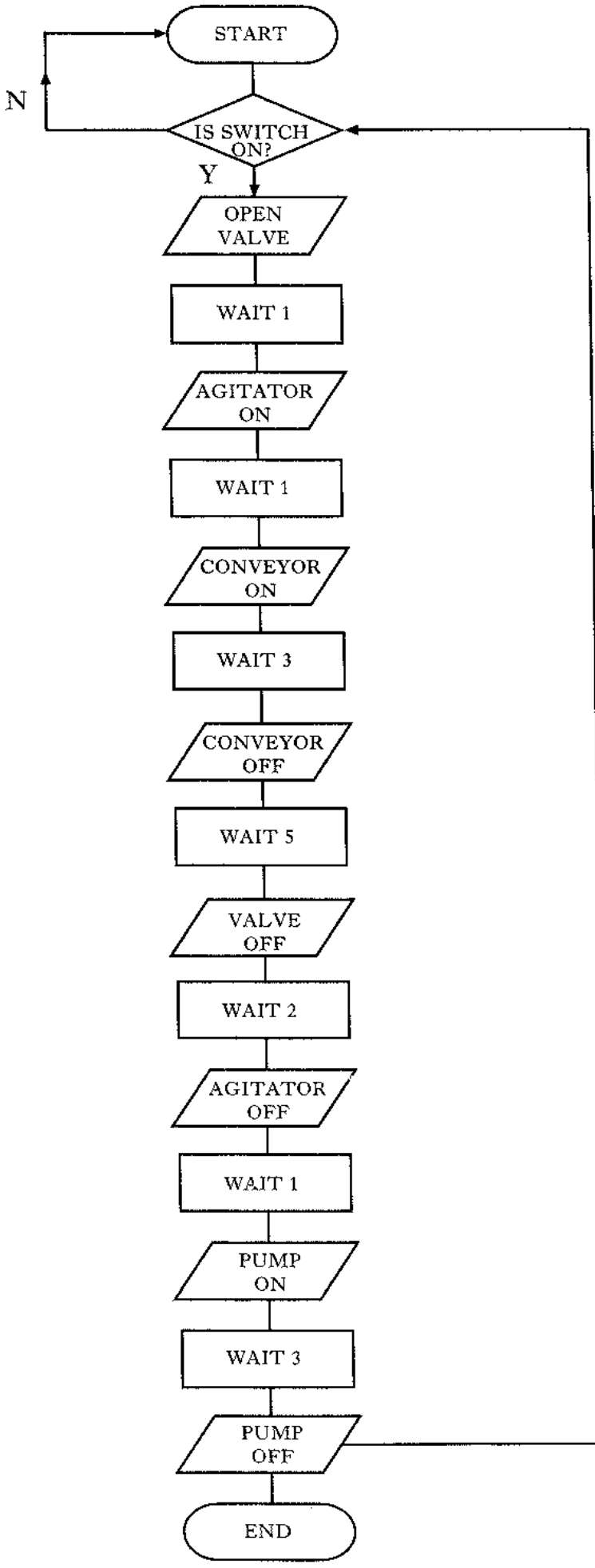
Therefore a minimum of eight bolts would be required. **1**

Marks

10

(20)

10. (*a*) Flow Chart



Marks

½ mark each block	**8**
loop	**1**
correct use of symbols	**1**

10

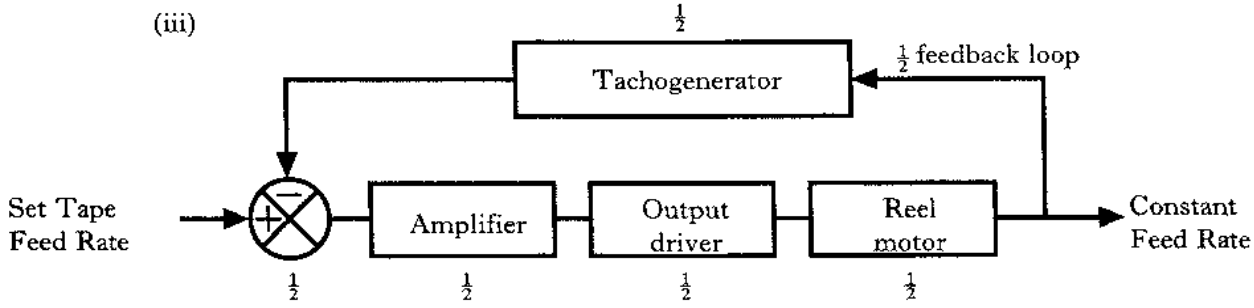
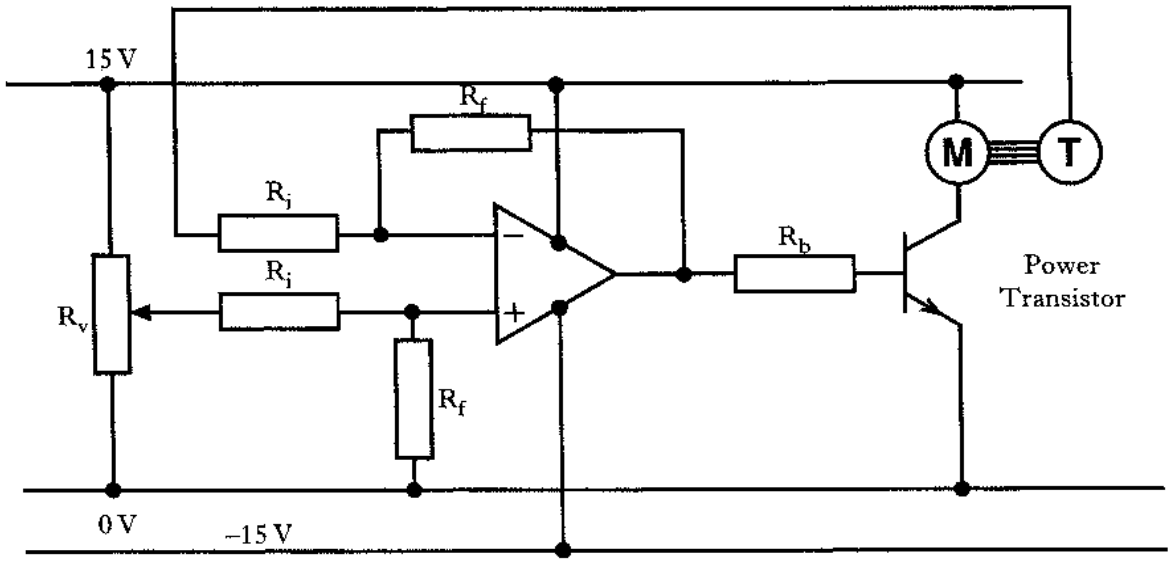
10. (continued)

Marks

(*b*) **Note: symbols could also be used for input and outputs pins**

```
let dirs = %11110000    :  set up DDR 0-3 in, 4-7 out                    1
main:  if pin0 = 1 then doit it     :  jump if switch on
       goto main                    :  else loop                         1

doit:  high 4           : open valve
       let mins = 1     : wait 1 minute
       call delay
       high 7           : agitator motor on
       let mins = 1     : wait 1 minute
       call delay

       high 5           : conveyor on
       let mins = 3     : wait 3 minutes          ½ mark each
       call delay                                 line              8

       low 5            : conveyor off
       let mins = 5     : wait 5 minutes
       call delay

       low 4            : close valve
       let mins = 2     : wait 2 minutes
       call delay

       low 7            : agitator motor off
       let mins = 1     : wait 1 minute
       call delay

       high 6           : pump motor on
       let mins = 3     : wait 3 minutes
       call delay
       low 6            : pump motor off

       goto main        : loop to start                                  10
```

(20)

		Marks
11. (*a*) (i)	Proportional Closed Looped Control.	**1**
(ii)	Difference Amplifier.	**1**
(iii)		**3**
(iv)		
	Diagram	**3**
	The target or goal speed of the motor is set by R_v.	**1**
	The difference amplifer compares the signal from R_v with the signal from the tachogenerator monitoring the motor speed.	**1**
	The difference between the signal is sent to the power transistor which provides the current to drive the motor faster/slower as appropriate.	**1** **6**
(*b*) (i)	Summing Amplifier.	**1**

(ii) Signal On

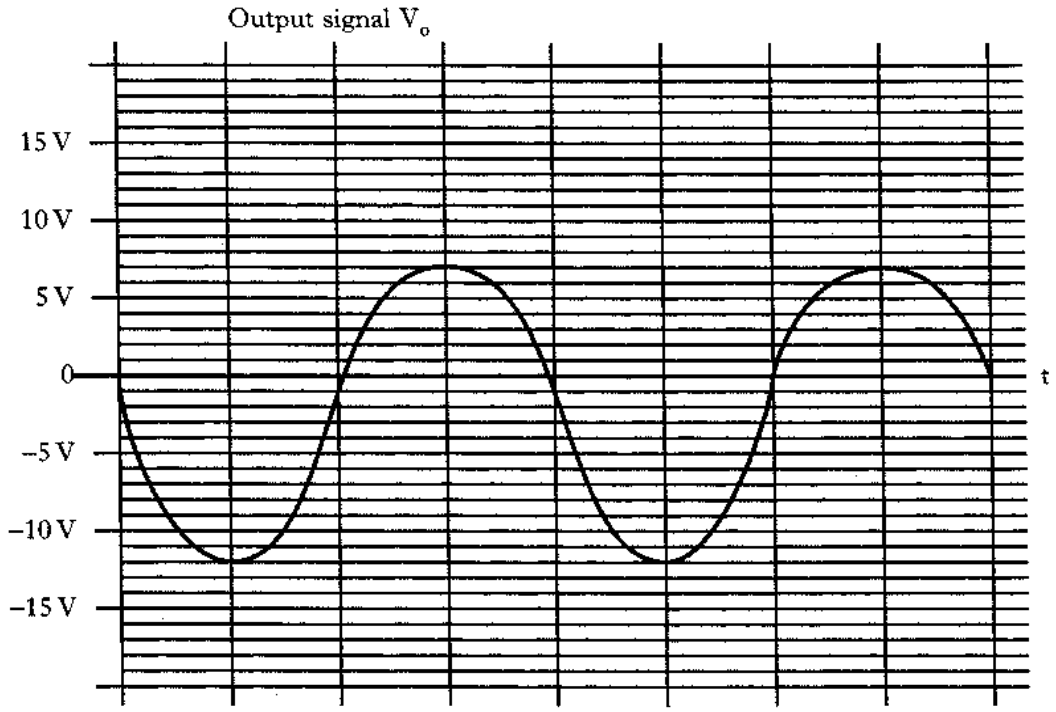
	V_{in} max mV	V_{in} min mV	A_v	V_o max V	V_o min V	
A	150	−150	−50	7·5	−7·5	**1**
B	500	0	−5	−2·5	−2·5	**1**
C	1	−1	−2	2·0	−2·0	**1**
				+7·0	−12·0	

11. (*b*) (continued)

Marks

(iii) One mark for each point correctly plotted on the graph.

Graph Point	0°	90°	180°	270°	360°
V_o	0	−12	0	+7	0



5

(20)

[END OF MARKING INSTRUCTIONS]