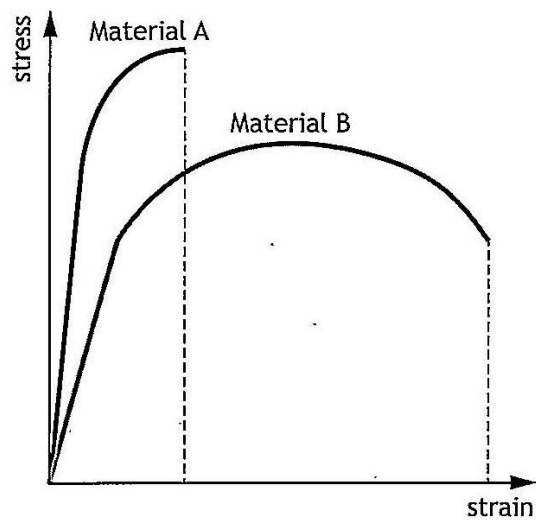


MARKS

SECTION 1 — 20 marks

Attempt ALL questions

1. The traces below show the stress-strain response of two materials when tested.



- (a) Name the value which may be found using stress and strain on the straight-line portion of each of the two.

1

Youngs Modulus

- (b) State a material property of Material A and Material B that can be interpreted from the whole of these traces.

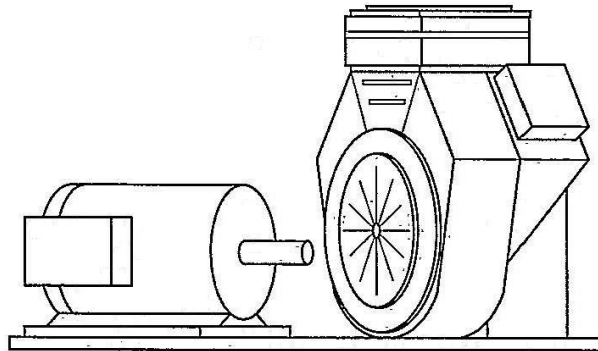
2

Material A Brittle

Material B Ductile

MARKS

2. An electric motor drive shaft is to be connected to an air compressor using a clutch.

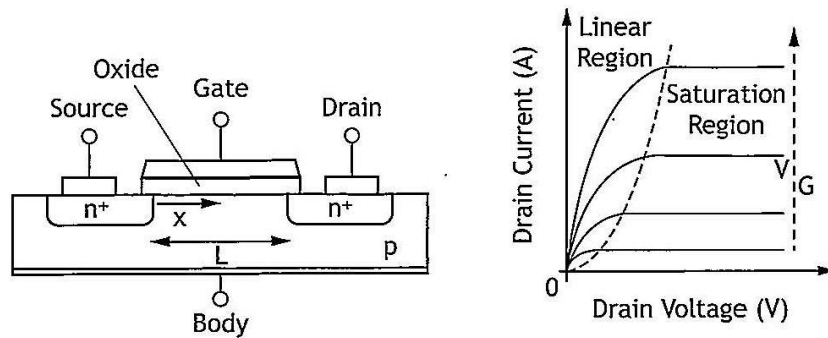


Explain one advantage and one disadvantage of using this coupling method.

- (a) Advantage It will allow the motor 2
to be engaged and disengaged
while it is running. It won't have
to be turned on and off saving energy
- (b) Disadvantage The clutch will wear 2
quickly and will need regular
replacing. This will cost a lot
of money if it is a regular process

MARKS

3. Diagrams of a MOSFET and its characteristic operation curves are shown below. A MOSFET can be connected as a voltage operated switch.



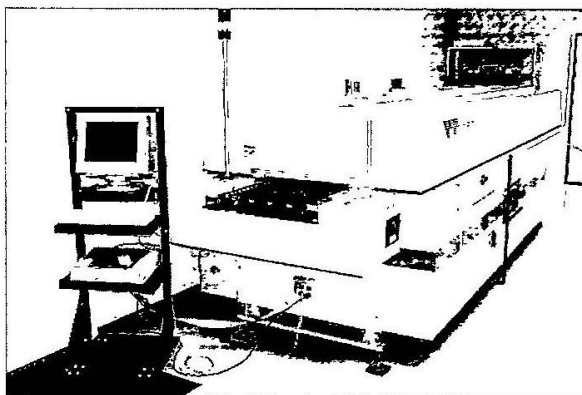
Describe the basic operation of a MOSFET switching device, making reference to the diagrams shown.

3

As the Mosfet saturates it provides a link and will allow current and voltage through from the source to the drain. Below a specific current or voltage the mosfet will not operate. This value is the Drain Current/Voltage of that mosfet and determines how it is used.

MARKS

4. The oven system shown is an example of the fact that the complexity of designing and producing many products has changed the traditional roles of engineers.



Electrical/electronic engineering requires specialisms in analogue electronics, digital electronics, programming and power.

Describe for one of these specialisms three specialist skills the engineer would require.

3

Skill 1 Programmable Control - must be
able to program microprocessors to
create closed loop control. Using flowcharts and
code

Skill 2 Be able to calculate Torque
and Velocity Ratios in order to
determine power

Skill 3 Using formulae to calculate energy
that can be used to find power

5. A local supermarket has decided to increase its floor area by one third. The current building is a framework assembly.

Describe the role of two engineers from different branches in the expansion project.

MARKS
E
W
A

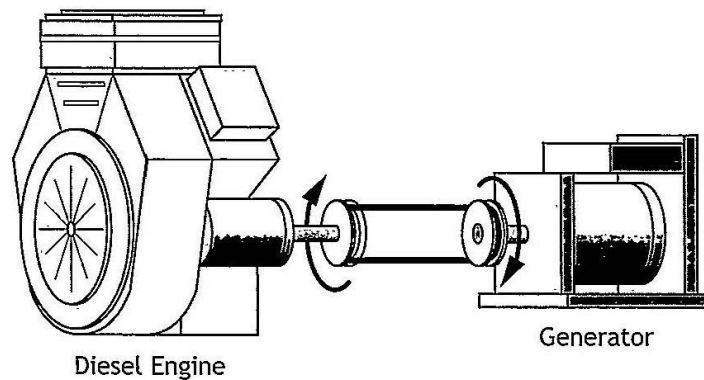
4

Engineer 1 STRUCTURAL ENGINEER would perform the calculations of stress and strain in the frame work, determining the forces in each member.

Engineer 2 MATERIALS AND COMPONENTS ENGINEER would take the calculations and select suitable materials for the framework to ensure it stays upright and can cope with the forces.

MARKS

6. A small portable generator driven by a diesel engine has an electrical load of 75A at 110V. The belt drive system has a 5% efficiency loss.



Calculate the power output from the diesel engine in kW.

3

$$\begin{aligned} \text{INPUT Power } P &= IV \\ &= 75 \times 110 \\ &= 8250 \text{ W} \\ &= 8.25 \text{ kW} \end{aligned}$$

$$\text{EFFICIENCY} = 95\%$$

$$\begin{aligned} \text{OUTPUT Power} &= \text{EFFICIENCY} \times \text{INPUT} \\ &= 0.95 \times 8.25 \\ &= 7.8375 \text{ kW} \end{aligned}$$

$$\begin{aligned} \text{INPUT} &= \frac{\text{OUTPUT}}{\text{EFFICIENCY}} \\ &= \frac{8.25}{0.95} \quad \text{INPUT Power} = 8.7 \text{ kW} \end{aligned}$$

MARKS

SECTION 2 — 70 marks

Attempt ALL questions

7. A home owner has asked an electronic engineer to design a burglar alarm system for a house. The house alarm system will sound a bell when the power switch is closed and either a pressure sensor under the carpet at the front door is closed or a switch is opened when any of the windows are lifted.

Assume all the switches to be a logic 0 when opened. A = Power switch, B = Pressure sensor, C = Window switches and Z = Bell.

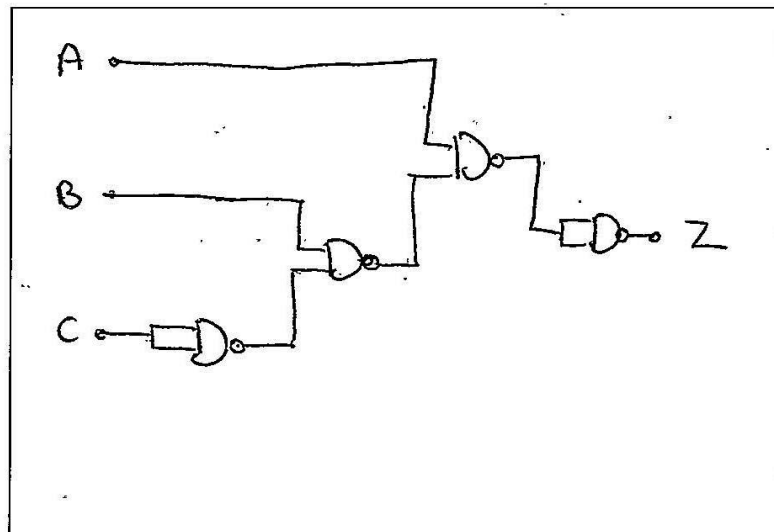
- (a) (i) Write a Boolean expression for the control of the bell using the specification provided.

3

$$Z = A \cdot (B + \bar{C})$$

- (ii) Draw an equivalent logic circuit for the Boolean expression using two input NAND gates only. Simplify if appropriate.

4



MARKS

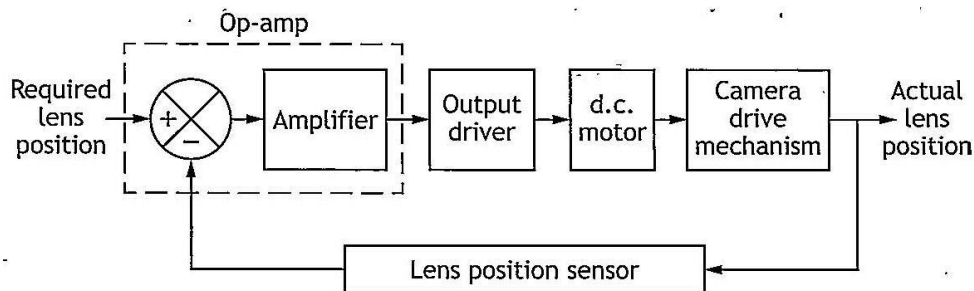
DC	
WR	
1	
MP	

7. (continued)

- (b) The home owner still has concerns over security, so has instructed the electronic engineer to install a camera into the system to monitor any intruders.

In order to focus an automatic camera, a control system uses information from the input sensors to create a signal representing the required lens position. It then adjusts the lens position by the means of a small d.c. motor.

The control diagram below shows the main sub-systems to the camera system.



- (i) State two possible configurations of op-amp that the engineer could have used in the design of the control system.

2

Inverting and Non-inverting
Difference and Comparator
Amplifier

- (ii) Compare the operation of the two control systems containing the two configurations of op-amp and select the more suitable system. Justify your answer

4

Comparator would allow to
values to be compared through
two voltages

Difference amplifier indicates
the set difference between two
inputs. Comparator is more suitable
as the two values have to be
compared.

MARKS

7. (continued)

- (c) Explain how pulse width modulation control may be used to vary the speed of the camera.

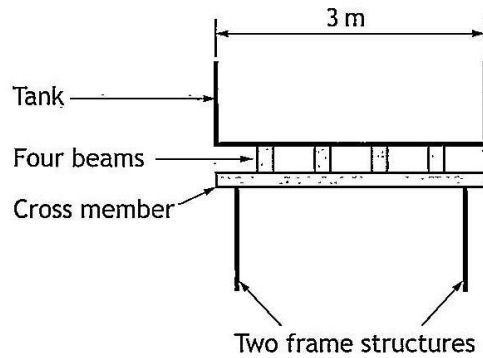
2

Increasing the mark and
Decreasing the space would cause
the motor to increase speed and
Decreasing the mark and Increasing
the Space would cause it to
decrease in speed.

MARKS

8. The water storage system below shows a water tank which is filled by an electrical pump. The tank with dimensions $3\text{ m} \times 3\text{ m}$ sits on four timber beams. The beams are secured to a cross member at one end and fixed into the wall at the other. Each beam carries an equal share of the water tank's weight.

The cross member is supported by two frame structures.



Front View

- (a) Calculate the maximum uniformly distributed load exerted on each beam if the water level in the storage tank does not exceed 1.5 metres. Ignore the weight of the tank.

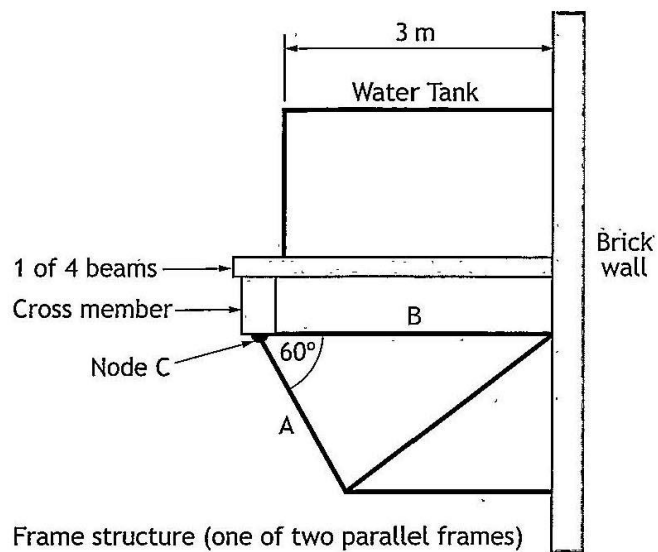
(1 m^3 of water has a mass of 1000 kg.)

4

$$\begin{aligned}
 V &= l \times b \times h \\
 &= 3 \times 3 \times 1.5 \\
 V &= 13.5\text{ m}^3 \\
 m &= V \times 1000 \\
 &= 13500\text{ kg} \\
 W &= mg \\
 &= 13500 \times 9.8 \\
 &= 132300\text{ N} \\
 &= 132.3\text{ kN} \\
 UDL &= \frac{132.3}{4} \\
 &= 33.1\text{ kN per beam}
 \end{aligned}$$

8. (continued)

MARKS



Side View

- (b) The figure above shows one of the frame structures which support the tank. The force exerted by the water in the tank at node C is 58.8 kN.
- (i) Calculate the magnitude and determine the nature of the forces in members labelled A and B.

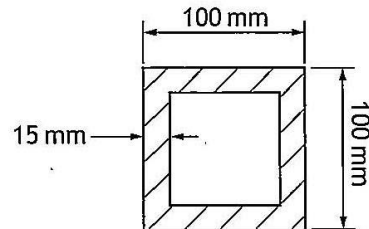
3

$$\begin{aligned}
 &\text{Node C} \\
 &\sum F_v = 0 && \sum F_H = 0 \\
 &A_v = 58.8 \text{ kN} && B = A_H \\
 &A_H = \frac{58.8}{\tan 60} && B = \underline{33.9 \text{ kN}} \\
 &A_H = 33.9 \text{ kN} \\
 &A = \sqrt{A_v^2 + A_H^2} \\
 &A = \sqrt{58.8^2 + 33.9^2} \\
 &A = \underline{\underline{67.8 \text{ kN}}}
 \end{aligned}$$

MARKS

8. (b) (continued)

Member A is a 100 mm × 100 mm square tubular section with a uniform wall thickness of 15 mm as shown below.



(ii) Calculate the stress present in member A.

3

$$\text{Stress} = \frac{F}{A}$$
$$\sigma = \frac{67000}{5100}$$
$$\sigma = 13.9 \text{ N/mm}^2$$
$$\sigma = \underline{13.9 \text{ Nmm}^{-2}}$$
$$A = (100 \times 100) - (70 \times 70)$$
$$= 5100 \text{ mm}^2$$

MARKS

8. (continued)

- (c) The water tank is filled using an electrical pump, rated at 230V and 15 A, which is located at ground level. The pump is 75% efficient and the filling pipe is located 6 metres above ground level.

Calculate the time it will take to fill an empty tank to a level of 1.5 metres.

5.

$$\begin{aligned}
 P &= IV \\
 &= 230 \times 15 \\
 &= 3450
 \end{aligned}$$

$$\begin{aligned}
 P_{\text{OUT}} &= 3450 \times 0.75 \\
 &= 2587.5
 \end{aligned}$$

$$\begin{aligned}
 E_p &= mgh \\
 &= 13500 \times 9.8 \times 6 \\
 &= 793800
 \end{aligned}$$

$$\begin{aligned}
 P &= \frac{E}{t} \\
 t &= \frac{E}{P} \\
 &= \frac{793800}{2587.5} \\
 t &= 306.8
 \end{aligned}$$

$$\begin{aligned}
 \text{Volume} &= 3 \times 3 \times 1.5 \\
 &= 13.5 \text{ m}^3
 \end{aligned}$$

$$\text{Mass} = 13500 \text{ kg}$$

MARKS
DO
WRIT
TI
MAI

9. The Queensferry Crossing is the largest civil engineering project undertaken in Scotland for a generation. The cable-stayed bridge is designed to relieve the pressure on the Forth Road Suspension Bridge, shown below, which is slowly weakening due to design flaws and a traffic volume double its design capacity.



The Forth Road Suspension Bridge

- (a) Describe one social, one economic and one environmental benefit of this project.

3

Social Will cut down on journey times
for drivers, by preventing them from
being held up traffic for as long

Economic Will provide jobs to local
businesses boosting the local
economy. Will also provide a job
for people who are out of work

Environmental Will reduce congestion
during peak times, reducing the
CO₂ emissions from cars and
other vehicles

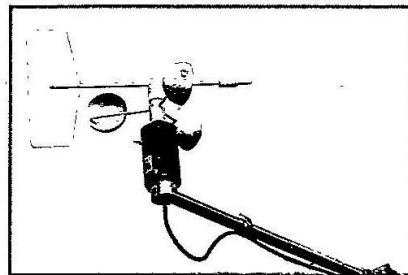
9. (continued)

- (b) The bridge control room continuously monitors conditions which could affect the safe operation of the bridge. One of the most important is wind speed.

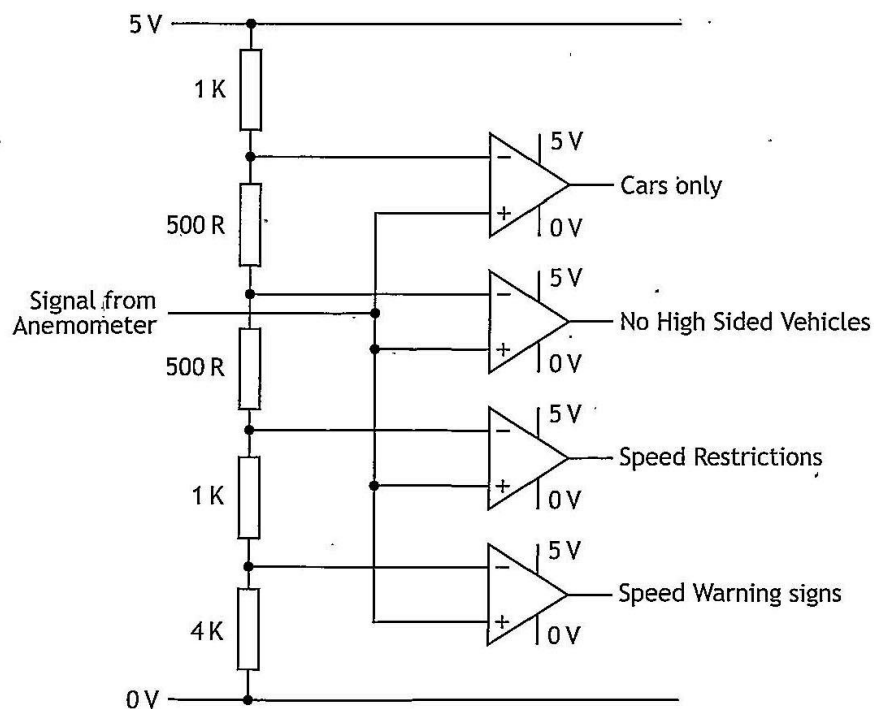
As wind strength increases there are four levels of response:

- Speed warning signs will be switched on.
- Speed restrictions are put in place.
- High sided vehicles are diverted away from the bridge.
- The bridge is closed to all vehicles except cars.

The wind is monitored by the anemometer shown below.



The anemometer gives an increasing voltage of $0.07\text{ V per ms}^{-1}$ as the wind speed increases. Part of the control circuit is shown below.



9. (b) (continued)

MARKS
DO NOT
WRITE IN
THIS
MARGIN

With reference to the circuit diagram opposite, calculate the wind speed which will:

- (i) switch on the Speed Warning signs;

2

$$V_1 = \frac{V_0}{A_v} = \frac{4.25}{4} = 1.06 \text{ V}$$

$$V(\text{ms}^{-1}) = \frac{1.06}{0.07} = \underline{\underline{15 \text{ ms}^{-1}}}$$

- (ii) switch on the No High Sided Vehicle signs.

2

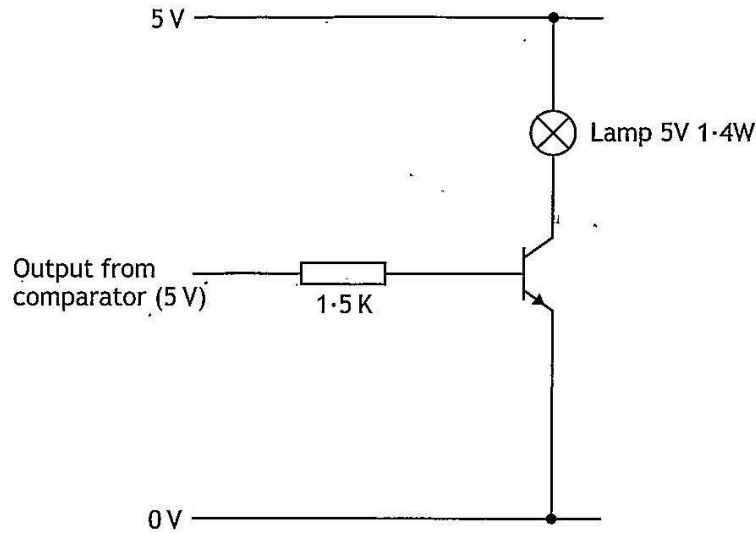
$$V_1 = \frac{V_0}{A_v} = \frac{4.25}{1} = 4.25 \text{ V}$$

$$V(\text{ms}^{-1}) = \frac{4.25}{0.07} = \underline{\underline{60.7 \text{ ms}^{-1}}}$$

MARK

9. (continued)

- (c) The warning lights on the controller's console have 5 V lamps which have a power rating of 1.4 W. The driver circuit for each light is shown below. The transistor is fully saturated when $V_{BE} = 0.7 \text{ V}$.



Calculate the minimum current gain required by the transistor.

4

Handwritten calculations for the lamp driver circuit:

$P = 1.4 \text{ W}$
 $I = P/V$
 $= \frac{1.4}{5}$
 $= 0.28 \text{ A}$

$V = IR$
 $I = V/R$
 $= 5/1500$
 $= 3.3 \text{ mA}$

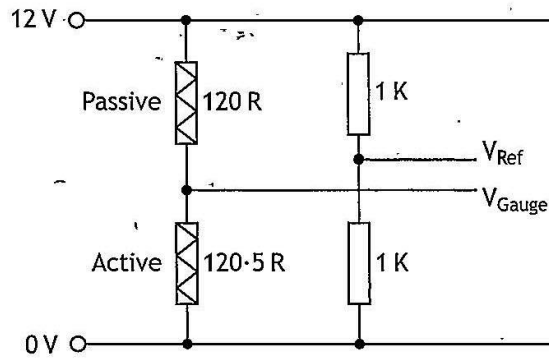
$h_{fe} = I_c / I_b$
 $h_{fe} = \frac{230}{3.3} = 69.7$

$P = 1.4 \text{ W}$
 $I = P/V$
 $= \frac{1.4}{5}$
 $I = 0.28$
 280 mA

MARKS

9. (continued)

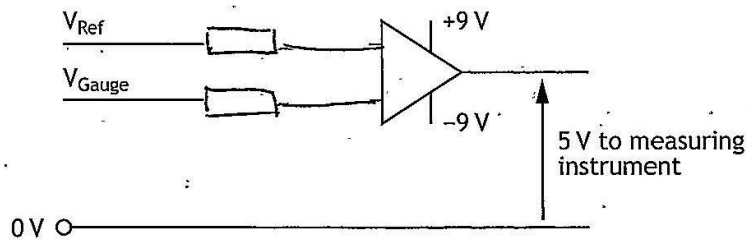
The instantaneous load at various points on the bridge is monitored using strain gauges attached to the support cables. When the cable is under maximum permitted strain, the resistance of the active gauge rises to 120.5Ω and the passive gauge remains at 120Ω . The sensing part of the circuit at maximum permitted strain is shown below.



The measuring instrument requires a voltage of 5 V to give a reading showing the maximum permitted strain.

- (d) Complete the circuit below, showing all component values, to provide the signal conditioning described. Working should be to six significant figures.

4



[Turn over

MARKS

9. (continued)

The maximum force on any cable is calculated at 4.7 MN. Each cable is made up of a number of strands of mild steel wires, each of which is 13 mm in diameter. A safety factor of 10 is applied.

(e) Calculate how many strands of wire will be required in the cable.

5

$$\begin{aligned}
 F_c &= F_{\text{max}} \times \text{Max Force} & \text{Fos} &= \frac{\text{Ultimate Stress}}{\text{Safe Stress}} \\
 &= 4.7 \text{ MN} & &= \frac{470}{10} \\
 & & &= 47 \text{ MN}
 \end{aligned}$$

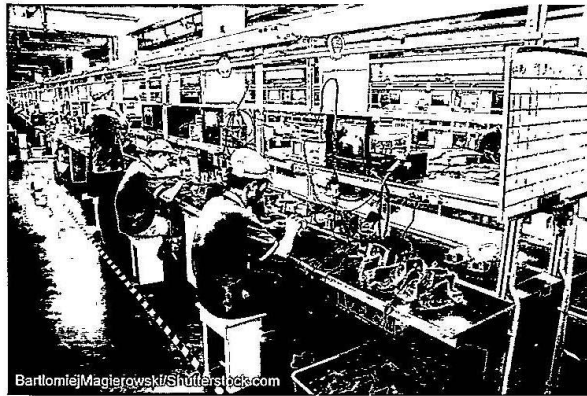
$$\begin{aligned}
 \text{SWS} &= \frac{\text{UTS}}{\text{Fos}} \\
 &= \frac{470}{10} \\
 &= 47 \text{ Nmm}^2
 \end{aligned}$$

$$\begin{aligned}
 \sigma &= F/a \\
 F &= \sigma \times a \\
 F &= 47 \times \frac{\pi \times 13^2}{4} \\
 F &= 47 \times 132.7 \\
 &= 6233.9
 \end{aligned}$$

$$\begin{aligned}
 \text{STRANDS} &= \frac{4.7 \text{ MN}}{6233.9} \\
 &= \frac{4.7 \times 10^6}{6233.9} = 753.9 \\
 &= \underline{\underline{754 \text{ strands}}}
 \end{aligned}$$

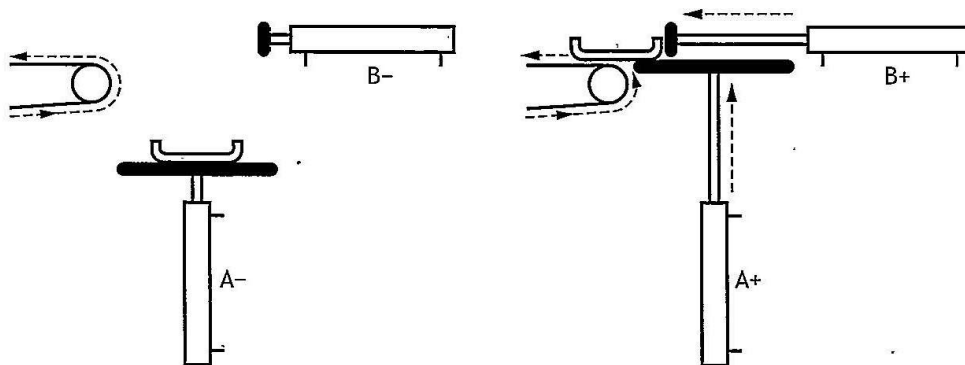
MARKS
DO NOT
WRITE IN
THIS
MARGIN

10. A factory which assembles smartphones uses a cellular assembly system.



Each cell is occupied by a technician who assembles the phone units. Each finished unit is then placed in a protective cradle before being carried off to the testing station on a conveyor belt. A two-cylinder automatic pneumatic system is used to raise the cradle up to the conveyor belt level and push the cradle on to the belt. When the technician presses a button the sequence will be A+ B+ B- A-.

A+ B+ B- A-



When designing the circuit it was found that the sequence could not be achieved using a single 5/2 valve for each cylinder. A third 5/2 valve to provide two "groups" of air was required

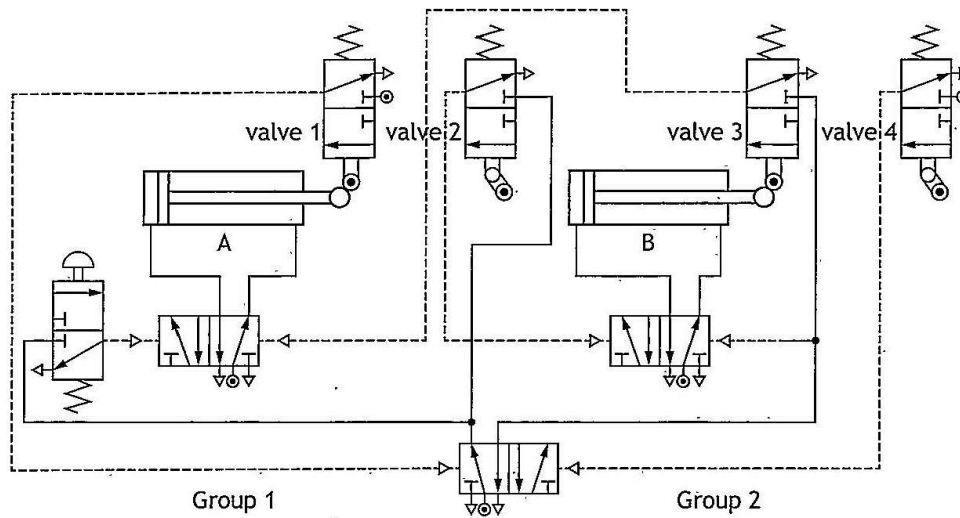
- (a) Explain, for this sequence, why this is the case.

2

The sequence has the B+.B- commands together and this causes the sequence to jam as it has two commands going into the same cylinder

10. (continued)

(b) The circuit diagram for this operation is shown below.



Describe the operation of the circuit starting when the technician presses the button.

7

Pressing the button sends pilot air to the first 3/2 valve and will outstroke Cylinder A, this actuates Valve 2 sending pilot air to the second 3/2 valve. Cylinder B will then outstroke and actuate Valve 4, this sends pilot air to the switching 3/2 which causes Cylinder B to instroke. This actuates valve 3 which makes cylinder A instroke actuating Valve 1.

MARKS

10. (continued)

It was found that the outstroke of cylinder B was too rapid, so a uni-directional restrictor was added to slow it down.

- (c) State and explain where the uni-directional restrictor should be placed in the circuit.

3

Position Between the S/2 and outstroke Part of Cylinder B

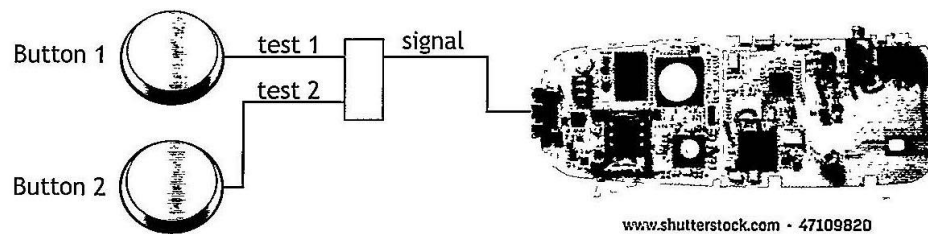
Explanation This will prevent all of the air reaching the cylinder at once, decreasing the force and therefore speed during the outstroke

[Turn over

MARKS

10. (continued)

Once at the testing station the phone circuit board undergoes a range of tests by applying signals to it. A microcontroller is used to provide these signals. The sequence of one of the test procedures is shown below.



- When the test 1 button is pressed the signal goes high for 320 ms and then goes low.
- When the test 2 button is pressed the signal is pulse width modulated in a 10 times repeat loop.
- Initially the MARK = 10 and the SPACE = 3
- Each time around the loop the MARK is decreased by 1 and the SPACE increased by 1

MARKS

10. (continued)

(d) Draw a flowchart for this sequence.

8

