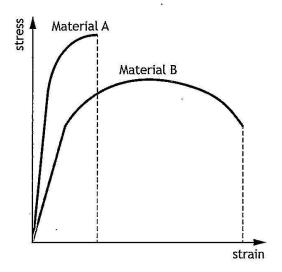MARKS

SECTION 1 — 20 marks

Attempt ALL questions

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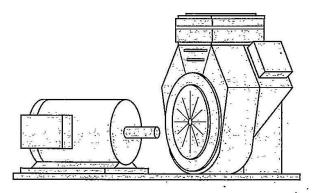

(a) Name the value which may be found using stress and strain on the **straight-line** portion of each of the two.

Youngs modulas　　　　　　　　　　　　　　　　　　　　　　　1

(b) State a material property of Material A and Material B that can be interpreted from the whole of these traces.　　　　　　　　　　2
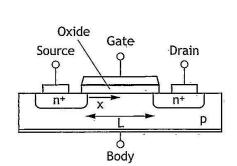
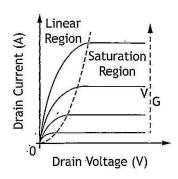Material A _Plastic_

Material B _Elastic_

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 ~~Efficient~~   2

Reliable and accurate

(b) Disadvantage Inefficient , bad for environent   2

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
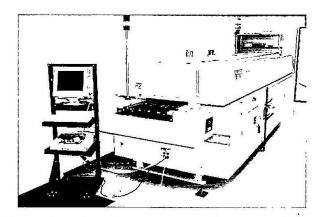
As negative electrons are attracted to the point once the x area is filled a current can flow and the source to drain are connected as the area can conduct. The mosfet will saturate at a certain current.

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 _Feedback system to get the heat right. desired voltage compared with actual voltage_

Skill 2 _Circuit work to make sure it works_

Skill 3 _Power, voltage, current and energy needed to work it and how it can be efficient eg not use energy when not in use_

MARKS

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.

4

Engineer 1 _Structural - adopting to the framework_
to make sure the new size can be
held

Engineer 2 _Mechanical - being able to work mechanics,_
cutting the files

MARKS

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

Generator

Diesel Engine

Calculate the power output from the diesel engine in kW.   **3**

$\text{Input} =$

$P_{in} = VI$
$\quad = 75 \times 110$
$\quad = 8250$

$n = \dfrac{P_{out}}{P_{in}}$

$0.95 = \dfrac{P_{out}}{8250}$

$P_{out} = 0.95 \times 8250 = 7837.5 W$
$\qquad\qquad\qquad = 7.84 \, kW$

MARKS

SECTION 2 — 70 marks
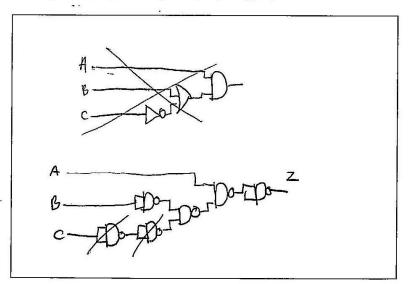
Attempt ALL questions

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
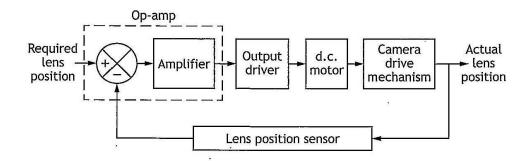
MARKS

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**

Comparator

Difference

(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 be more suitble as a desired voltage (Vref) can be compared with the actual voltage and then be adjusted * where a difference of op amp has two input voltages and amplifys the difference.

* Like in the systems diagram.

7.   (continued)

(c) Explain how pulse width modulation control may be used to vary the
speed of the camera.   2
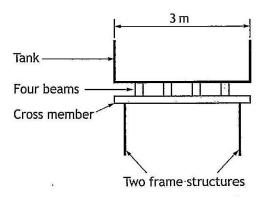
Pulse width modulation can be used as
it can easily control the speed of the
camera as voltage and time can be adjusted
to slow down. Can also work with the
comparator op amp output. If MARK and TIME
should be altered

MARKS

8. The water storage system below shows a water tank which is filled by an electrical pump. The tank with dimensions 3 m × 3 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.
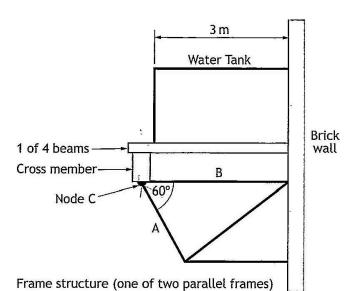
(1 m³ of water has a mass of 1000 kg.)   4

$m = 1.5 \times 3 = 4.5 \times 1000 = 4500 \, kg$

$W = 4500 \times 9.81 = 44145 N$

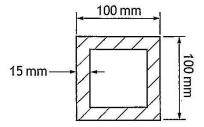$F = \dfrac{44145}{4} = 11036 N$

8.   (continued)

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**

Handwritten working:

$$\tan\theta = \frac{O}{A}$$

$$A = \frac{58.8}{\tan 60} = 33.9 \text{ kN}$$

$$B = 33.9 \text{ kN tension}$$

$$\sin\theta = \frac{O}{H}$$

$$H = \frac{58.8}{\sin 60} = 67.9 \text{ kN}$$

$$A = 67.9 \text{ kN compression}$$

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.

100 mm

15 mm →

100 mm

(ii)   Calculate the **stress** present in member A.   3

$F = 67.9$ kW

$$\sigma = \frac{F}{A} = \frac{67900}{5100} = \underline{13.31\ N\text{mm}^{-2}}$$

$A = 100 \times 100$ $A = 70 \times 70$
$= 10000$ $= 4900$
         $A = 5100\ mm^2$

8. (continued)

(c) The water tank is filled using an electrical pump, rated at 230 V 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

$P_{in} = 230 \times 15 = 3450 \text{ w}$

$P_{out} = 3450 \times 0.75$
$= 2587.5 \text{ w}$

$E = mgh$
$= 4500 \times 9.8 \times 6$
$= 264600 \text{ J}$

$t = \frac{E}{P} \not{}$
$= \frac{264600}{2587.5}$
$= 102.3 \text{ s}$

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 help people travel around as they wont have to ~~close~~ make a detour when maintaining and closing the Suspension bridge

Economic Give more jobs to build new bridge, workers wages will go back into the economy

Environmental Harmful gases may be released Manafacturing the bridge and effect the environment
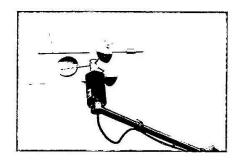
MARKS

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.
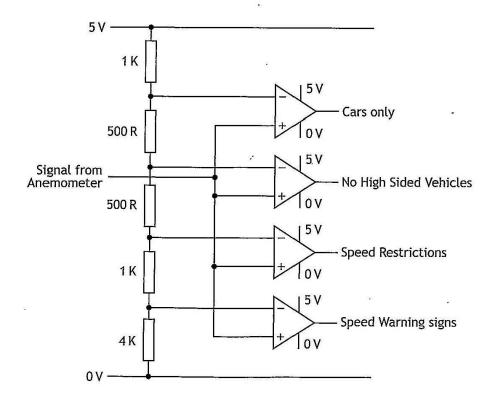
As wind strength increases there are four levels of response:

- 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 $0.07\,V$ per ms^{-1} as the wind speed increases. Part of the control circuit is shown below.

9. (b) (continued)

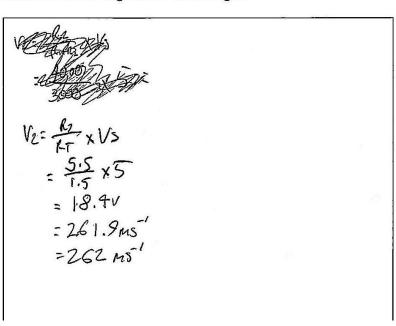With reference to the circuit diagram opposite, calculate the wind speed which will:

(i) switch on the Speed Warning signs;   **2**

$$V_2 = \frac{R_2}{R_1+R_2} \times V_s$$

$$= \frac{4}{3} \times 5 = 6.666^-$$
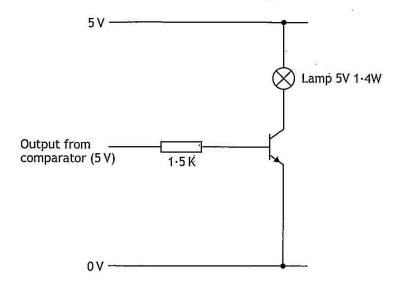
$$= 6.7V$$

$$\frac{6.7}{0.07} = 95.7 \, ms^{-1}$$

(ii) switch on the No High Sided Vehicle signs.   **2**

$$V_2 = \frac{R_2}{R_T} \times V_s$$

$$= \frac{5.5}{1.5} \times 5$$

$$= 18.4V$$

$$= 261.9 \, ms^{-1}$$

$$= 262 \, ms^{-1}$$

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 $V_{BE} = 0.7$ V.

Calculate the minimum current gain required by the transistor.   4
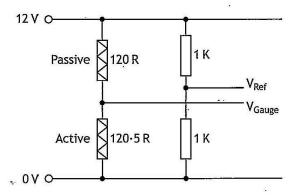
$V = IR$

$I = \dfrac{V}{R} = \dfrac{4.3}{1600} = 0.00287A$

$P = VI$

$I = \dfrac{P}{V} = \dfrac{1.4}{5} = 0.28$

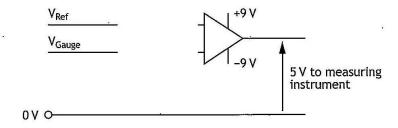$h_{FE} = \dfrac{0.28}{0.00287} = \underline{\underline{97.6}}$

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 $120 \cdot 5\,\Omega$ and the passive gauge remains at $120\,\Omega$. 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

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**

$$F = 4.7 MN$$

$$A = \frac{\pi d^2}{4} = \frac{132.73 \times 10^{-4}}{}$$

$$= 132.7 mm^2$$

$$\text{Factor of safety} = \frac{\text{Ultimate load}}{\text{Safe working load}}$$

$$\text{Safe working load} = \frac{4.7 \times 10^6 \times 10}{10} = 4.7 \times 10^7$$

$$\sigma = \frac{F}{A} = \frac{4.7 \times 10^7}{132.7} = 354182.4 \, Nmm^{-2}$$

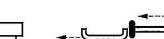$$\frac{354182.4}{430} = 823.7$$
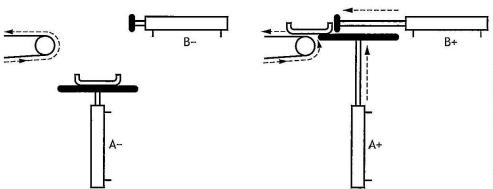
$$= 824 \text{ strands}$$

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
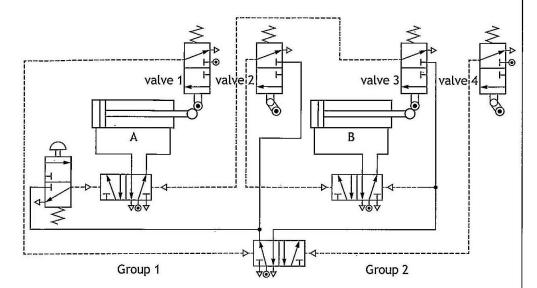
(a) Explain, for this sequence, why this is the case.   2

A third 5/2 valve is required so that the system could repeat itself and instroke and outstroke each cylinder

MARKS

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

When the button is pressed pilot air actuates the 5/2 which sends working air to actuate cylinder A. This actuates valve 2 sending pilot air to the 5/2 which outstrokes cylinder B which actuates valve 4 which sends pilot air through group 2 to the 5/2 valve which sends working air to the 5/2 valve and instrokes cylinder B and actuates valve 3 (with T peice) which sends pilot air to the 5/2 valve which instrokes cylinder A with working air

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.
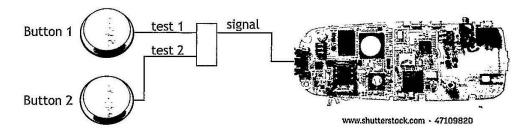
3

Position _Exhaust of cylinder B when outstroking_

Explanation _This will slow the exhaust down_
which makes the movement smoother than
the other side.

[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.

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- 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