**Victorian Certificate of Education
2013**

STUDENT NUMBER

Letter

Figures

Words

SYSTEMS ENGINEERING
Written examination

Monday 18 November 2013

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 10.45 am (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of questions to be answered	Number of marks
A	20	20	20
B	21	21	80
			Total 100

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
- Question and answer book of 26 pages including formulas on page 26.
- Answer sheet for multiple-choice questions.

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- All calculations must show appropriate formulas and working.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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SECTION A – Multiple-choice questions

Question 1

The gear set shown above is called a

A. rack and gear set.

B. worm and gear set.

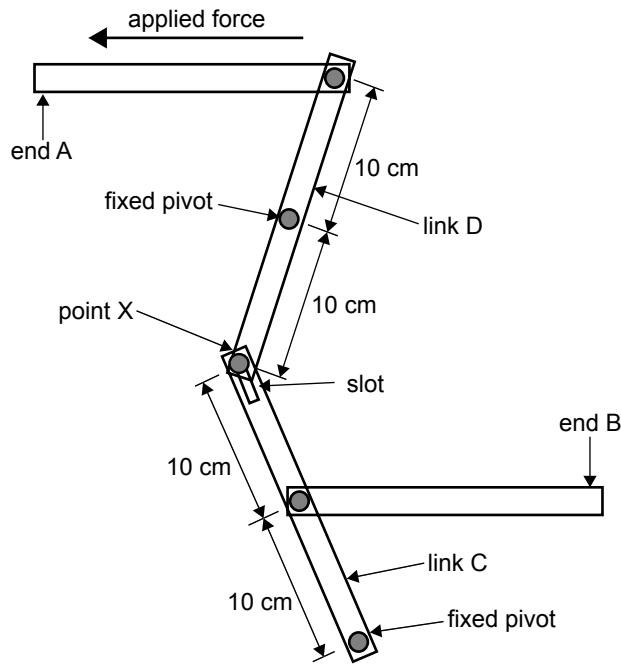**C.** rack and pinion set.

D. worm and pinion set.

Question 2
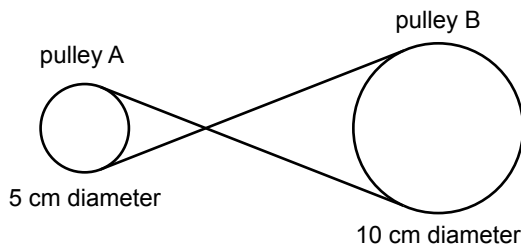
Pulley A, shown above, is 5 cm in diameter and rotates at 40 rpm in a clockwise direction.

How fast and in what direction is pulley B rotating?

A. 20 rpm, clockwise

B. 20 rpm, anticlockwise

C. 80 rpm, clockwise

D. 80 rpm, anticlockwise

Use the following information to answer Questions 3–5.

Question 3

Which one of the following best describes point X on the end of link D in the diagram above?

A. load

B. effort

C. fulcrum

D. mechanical advantage
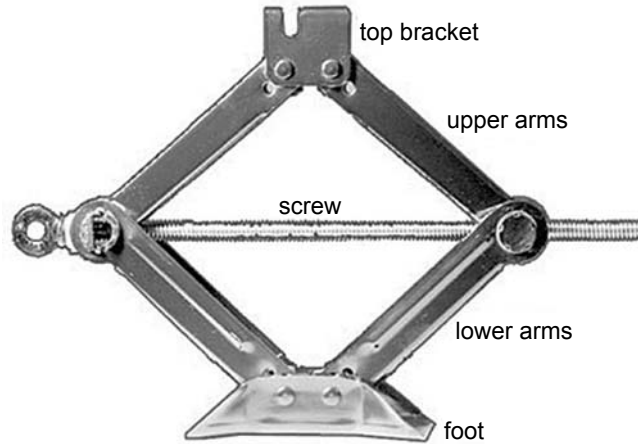
Question 4

A 100 N force is applied to end A.

If the diagram above is to scale, the force on end B will be closest to

A. 100 N to the left.

B.   50 N to the right.

C. 100 N to the right.

D. 200 N to the right.

Question 5

Link C is a

A. first-class lever.

B. second-class lever.

C. third-class lever.

D. fourth-class lever.

Question 6

A scissor jack is often used to lift motor vehicles.
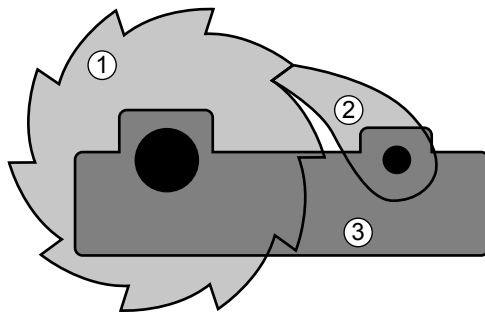
The scissor jack shown above converts rotary motion to

A. lift.
B. force.
C. linear motion.
D. mechanical advantage.

Question 7

Friction drive is used in many mechanical applications.

Which one of the following devices relies on friction for drive?

A. gear train
B. drive shaft
C. pulleys and belts
D. chains and sprockets

Question 8

The device shown above is used to allow motion in one direction only.

What is the part that is labelled 2 on the device?

A. a pawl
B. a latch
C. a ratchet
D. a clacker

Question 9

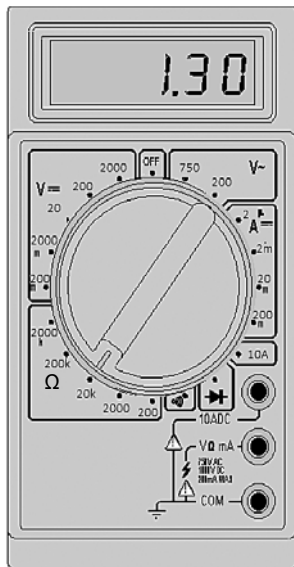Ammeters are usually connected for test purposes in

A. pairs.

B. series.

C. parallel.

D. combination.

Question 10

A battery charger is rated at 2 A and is 75 per cent efficient.
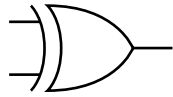
How long will it take to charge a 12 Ah battery?

A. 4.5 hours

B. 6 hours

C. 8 hours

D. 9 hours

Question 11

The reading on the multimeter shown above is

A. 13 k

B. 1.30 V

C. 1.30 Ω

D. 1300 Ω

Question 12

Which one of the truth tables shown below represents an exclusive OR (XOR) gate, as shown above?

A.

A	B	Z
0	0	0
0	1	0
1	0	0
1	1	1

B.

A	B	Z
0	0	0
0	1	1
1	0	1
1	1	1

C.

A	B	Z
0	0	0
0	1	1
1	0	1
1	1	0

D.

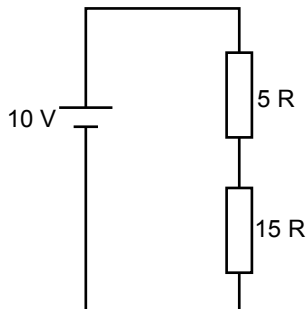| A	B	Z
0	0	1
0	1	1
1	0	1
1	1	0

Question 13
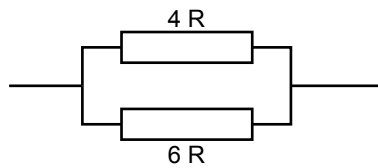
What is the total resistance of the circuit shown above?

A. 2.0 Ω

B. 2.4 Ω

C. 10.0 Ω

D. 24.0 Ω

Question 14

What is the total current in the circuit shown above?

A. 0.5 A

B. 2 A

C. 20 A

D. 150 mA

Question 15

The purpose of heat sink pliers is to

A. hold small components when tightening fasteners.

B. assist with avoiding dry solder joints when constructing an electrical circuit.

C. hold the circuit board safely when constructing an electrical circuit.

D. absorb heat during the soldering of components when constructing an electrical circuit.

Question 16
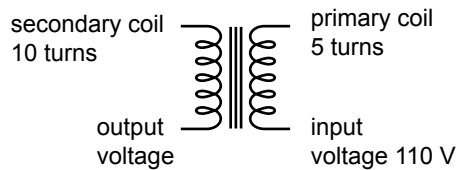
What is the output voltage of the transformer shown above?

A.   2 V

B.   55 V

C.   220 V

D.   550 V

Question 17

After researching the feasibility of and alternatives for a product, the next step in the systems engineering process is to

A.   design and model the system.

B.   test and analyse the performance.

C.   plan and fabricate the subsystems.

D.   identify and document the problem.

Question 18

When a new product, such as a new car, is designed for the market, there is usually extensive field testing carried out on the product.

The purpose of field testing is to check whether

A.   people like the product.

B.   the product will sell well.

C.   the product has the right colour range.

D.   the product performs to the design requirements.

Question 19

Which one of the energy sources listed below is renewable?

A.   coal

B.   biomass

C.   natural gas

D.   petroleum oil

Question 20

A small pedestal drill has a yellow safety line marked around its base on the floor.

The yellow safety line defines an area that

A.   no person should enter.

B.   can be part of a walkway.

C.   is accessed only by the operator of the drill.

D.   requires the wearing of hearing protection.

SECTION B

Instructions for Section B
Answer **all** questions in the spaces provided.
Unless indicated, the diagrams are not to scale.

The following information relates to Questions 1–20.

Carmen San Remo is in charge of the local sports field. To make more efficient use of her time, she has decided to build a robot lawnmower that will be used to mow one of the ovals. It must have the following design features.

- easy to manoeuvre
- safe to use
- electric powered
- docking/recharge station
- variable cutting height
- economical to make and operate
- capable of automatic mowing

Question 1 (2 marks)

Give two safety issues that need to be considered when designing the robot lawnmower.

1. _____

2. _____

Question 2 (2 marks)

Carmen does not want to have big clumps of grass left on the field. Her first option is to collect the lawn clippings and put them in a green waste bin. Her second option is to use high-speed blades to chop the grass into fine pieces that are left on the field as mulch.

a. Identify **one** environmental advantage of leaving the lawn clippings on the field over collecting the grass and disposing of it in a green waste bin.   1 mark
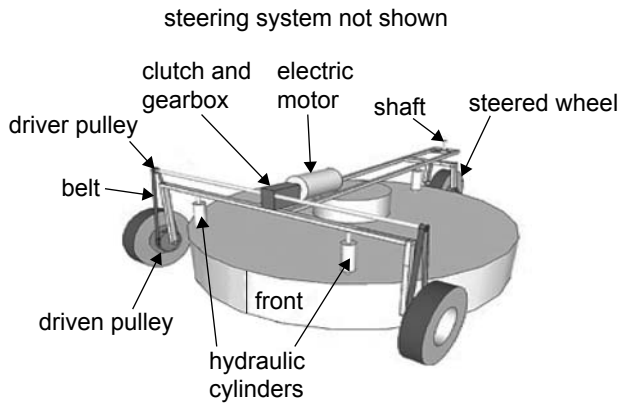
_____

_____

_____

b. Describe how deciding to leave the lawn clippings on the field would affect the design of the robot lawnmower.   1 mark

_____

_____

_____

Question 3 (2 marks)

It is possible to have a two-wheel independent drive and castor wheel, or a single drive and steering system. Option 2 below will require the castor wheel to be controlled using a steering mechanism.
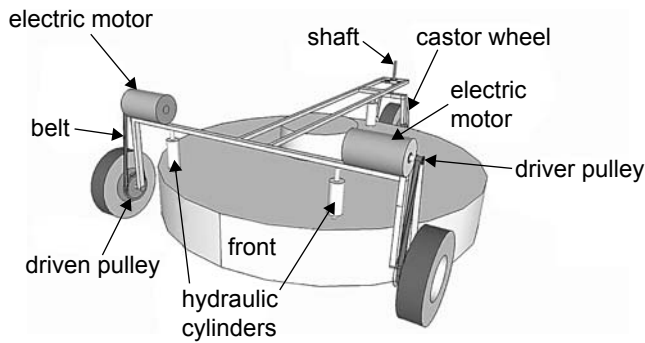
Option 1

Option 2

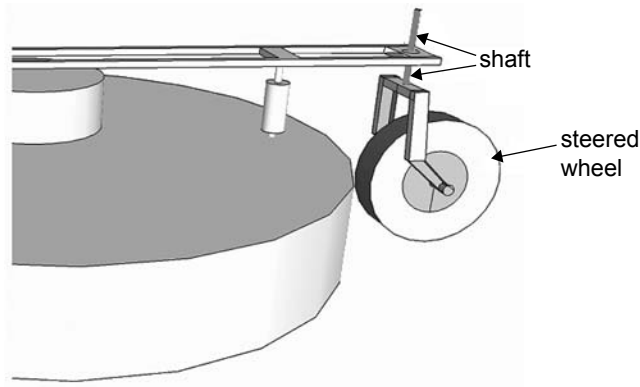**a.**   Describe how option 1 would be steered.   1 mark

_____

_____

b.   Why would option 1 be more manoeuvrable?   1 mark

_____

_____

Question 4 (6 marks)

a. Design an electric-powered steering mechanism for the robot lawnmower. Draw your design on the diagram shown below. 3 marks

b. Explain how the steering system that you have designed operates. 3 marks

_____

_____

_____

_____

Question 5 (2 marks)

Carmen would like the wheels of the robot lawnmower to rotate at two revolutions per second.

Calculate the speed of the robot lawnmower given that the circumference of the wheel is 1 m.

You must show your working.

_____

_____

Question 6 (7 marks)

A pulley ratio of 25:1 is needed to gain the required reduction in revolutions per second in the pulley system. This is shown in the diagram below.
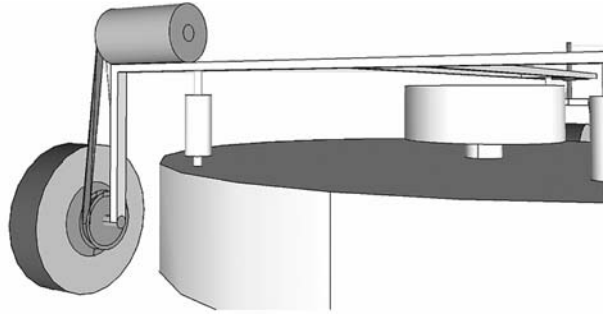
a.   Calculate the revolutions per second of the electric motor, given that the wheels rotate at 2 revolutions per second.   1 mark

_____

_____

**b.**   The driven pulley has a diameter of 250 mm.
Calculate the diameter of the driver pulley.   1 mark

_____

_____

c.   Suggest why a very small driver pulley may cause problems with the operation of the robot lawnmower.   1 mark

_____

_____

d.   The torque of the driven pulley is 75 Nm.
Calculate the force applied by the drive belt. You must show your working.   2 marks

_____

_____

_____

e.   Calculate the driving force of the wheels on the ground. You must show your working.   2 marks

_____

_____

_____

Question 7 (4 marks)

The pulley ratio of 25:1 is too large for a single-pulley system, so Carmen decides to use a compound-pulley system, as shown below.

driver pulley on motor

pulley A

pulley B

driven pulley on wheel

not to scale
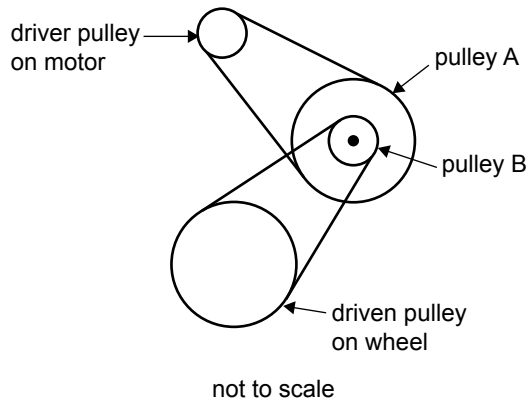
The diameter of the driver pulley on the motor is 30 mm. Many pulleys are available in the following diameters: 30 mm, 50 mm, 70 mm, 100 mm, 120 mm and 150 mm.

a. Calculate the diameters of the pulleys required in order for the robot lawnmower to operate as shown above. Write the diameters in the table below and show any working in the space provided. 3 marks

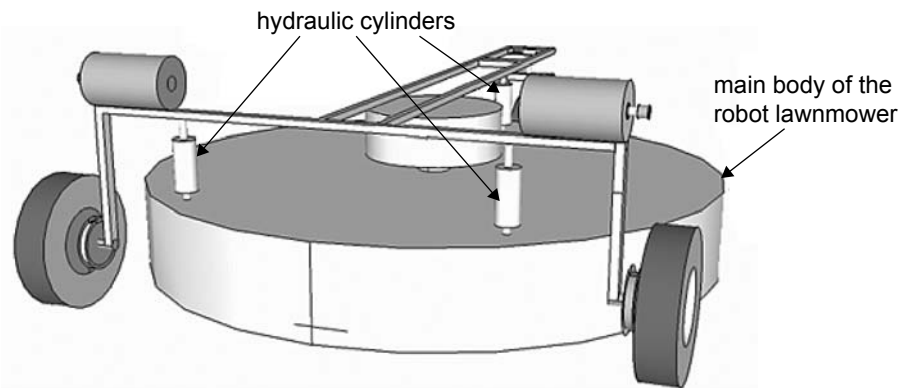|	Diameter of pulley (mm)
driver pulley	30
pulley A	
pulley B	
driven pulley	

b. Identify **one** modification that can be made to the pulley system so that the tension of both belts can be adjusted easily. 1 mark

_____

_____

Question 8 (2 marks)

The main body of the robot lawnmower is kept suspended above the ground by the action of three hydraulic cylinders, as shown below.


Carmen has a choice of four different hydraulic cylinder designs. Three of the designs are shown below with the blades at their lowest position. Hydraulic fluid is pumped into the cylinders under pressure.

Option A   **Option B**   **Option C**
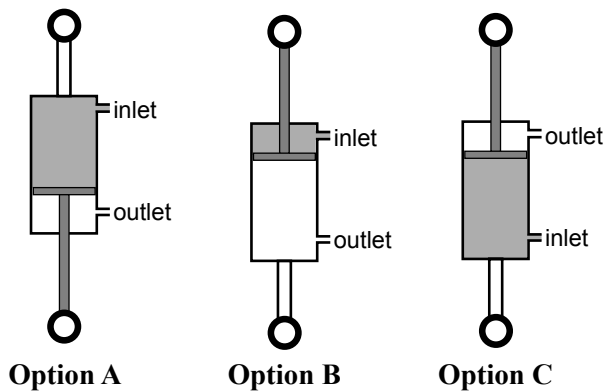
a.   Identify which of the three hydraulic cylinder designs shown above would be best to raise the
         blades.   1 mark

         _____

b.   Give **one** reason for selecting this option.   1 mark

         _____

Question 9 (3 marks)

Carmen decided to use a different hydraulic cylinder, as shown below.
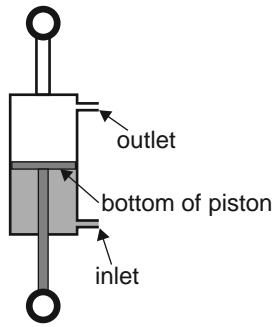
The area of the bottom of the piston in contact with the hydraulic fluid is 1.00×10^{-3} m^2. The force acting on each piston is 60.0 N.

Calculate the hydraulic pressure in the cylinder. Give your answer correct to three significant figures.

_____

_____

_____
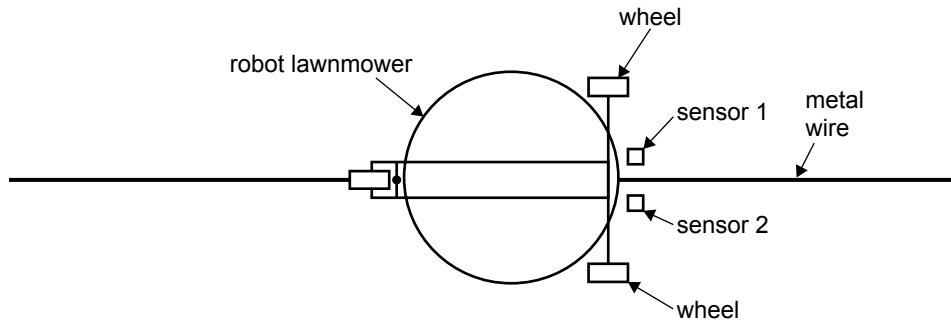
Question 10 (3 marks)

A hydraulic plunger pump is used to create hydraulic pressure.
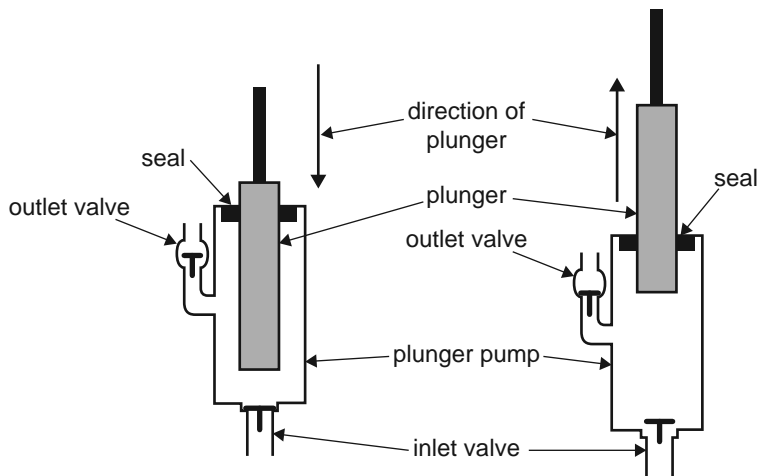
Describe how the hydraulic plunger pump shown above works.

_____

_____

_____

_____

Question 11 (3 marks)

The robot lawnmower is to follow a metal wire that is just below the surface of the grass field.

The top view of the robot lawnmower is shown below.

Initially, Carmen used a sensor that acted like a switch to produce a signal, as shown in the voltage–time graph below. This signal is then used as an input to a microcontroller.

The sensor/switch is closed when the robot is close to the wire.
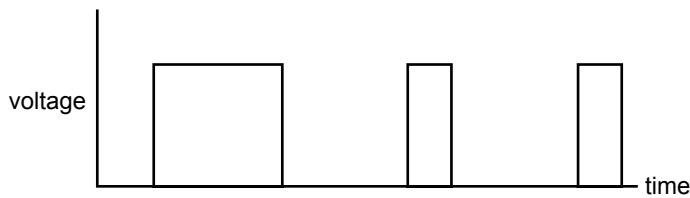
a.   Why is the signal shown a digital signal?   1 mark

_____

b.   Complete the simplified circuit diagram below that could produce a signal as shown in the voltage–time graph above using the components given.   2 marks
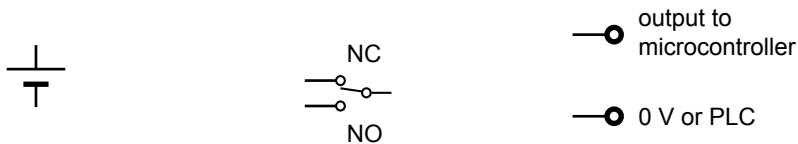
Question 12 (4 marks)

Carmen found that the robot lawnmower wandered away from the wire too much, so she decided to use a metal detector to detect the wire instead of a magnetic reed switch. Two of these metal detector circuits are used in place of the magnetic reed switches. A circuit diagram is shown below.
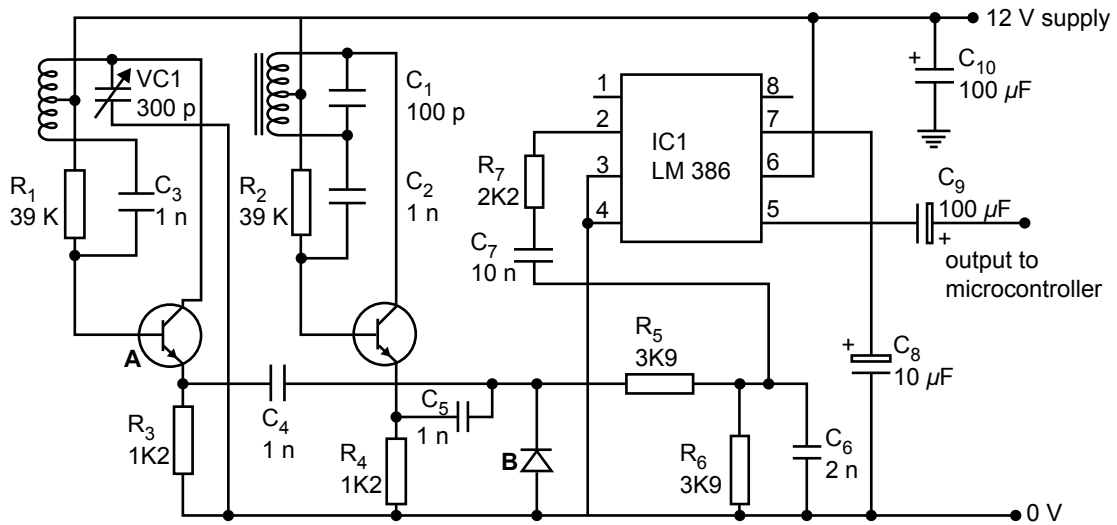
a. How many fixed capacitors are shown in the circuit above? 1 mark

_____

b. What is the basic function of a capacitor? 1 mark

_____

c. What is the voltage between pins 6 and 3 on IC1? 1 mark

_____

d. Give the four-colour code of resistor R_2 if it has a tolerance of 5 per cent. 1 mark

_____

Question 13 (4 marks)

The metal detector can be made more sensitive by connecting a resistor in series with a capacitor between pins 1 and 8 of IC1.

a. Complete the diagram below to show how this can be done.   2 marks
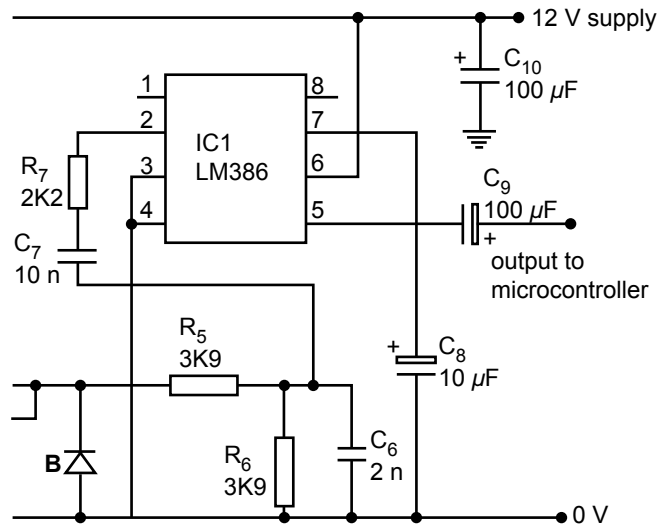
b. Calculate the current through R_6 if the voltage across it is 1.2 V. You must show your working.   2 marks

_____

_____

Question 14 (2 marks)

The peak voltage of the signal from each metal detector decreases with distance, as shown below.
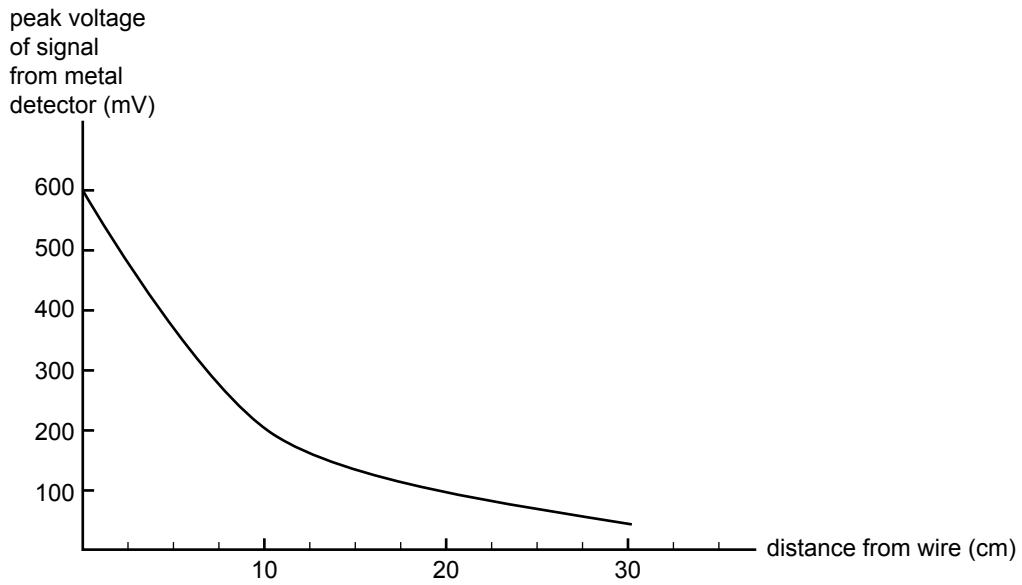
a.   If the metal detector is 10 cm from the wire, what is the output voltage of the sensor?   1 mark

_____

b.   For this application, briefly explain why an analog input signal to the microprocessor would
be better than a digital signal.   1 mark

_____

_____

Question 15 (9 marks)

Carmen uses a microcontroller for the robot lawnmower. Two of the inputs are the metal detectors for the metal wire. The microcontroller is then used to steer the robot lawnmower. The top view of the robot lawnmower is shown below.

a.   Identify whether the robot lawnmower is an open-loop or closed-loop system.   1 mark

_____

_____

b.   What happens to the outputs of sensor 1 and sensor 2 on the moving robot lawnmower as the
metal wire bends to the left?   2 marks

sensor 1 _____

sensor 2 _____

c.   Explain how the outputs of the metal detectors affect the speed of electric motor 1 and electric
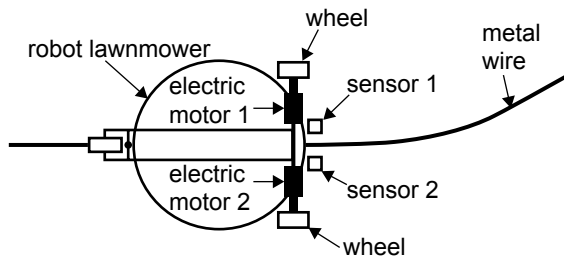motor 2.   2 marks

_____

_____

The microcontroller has the two metal detectors as inputs and the two electric motors as outputs.
The pin configuration of an 8-pin microcontroller is given below.
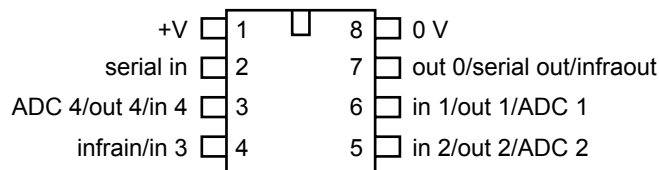
d.   List all of the pins that the analog metal detectors could be connected to.   2 marks

_____

e.   List all of the pins that the motors could be connected to.   2 marks

_____

Question 16 (3 marks)

The microcontroller is not powerful enough to drive the motors. The circuit below is used.
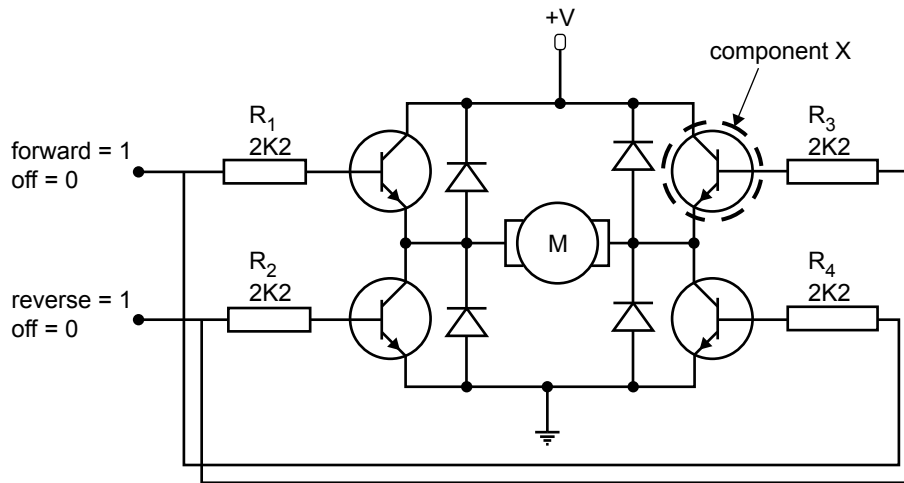
Figure 1

a.   Identify component X, which is labelled in Figure 1 above.   1 mark

_____

b.   What is the purpose of component X in this circuit?   1 mark

_____

c.   The motor can work only when one of the inputs is high.
        What type of logic gate should be used to ensure that only one input is always high?   1 mark

_____

Question 17 (4 marks)

Carmen decides to design her own circuit board for the circuit shown in Figure 1. A partially complete circuit board is shown below.
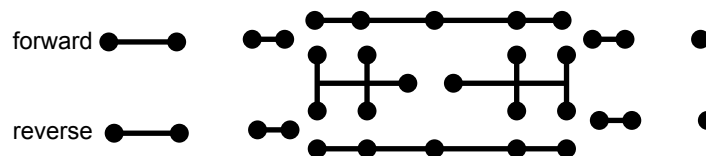
a.   Complete the missing tracks on the circuit board shown above.   2 marks

b.   Write an X in the position where you would place one of the diodes.   1 mark

c.   Write a Y where you would connect the positive of the supply voltage.   1 mark

Question 18 (5 marks)

The robot lawnmower is rated at 1.5 kW and takes two hours to mow the field.

Carmen thinks that a 200 W solar panel is large enough to supply the energy for the battery of the robot lawnmower. In winter, there is an average of four hours of sunlight per day.

a.   Calculate how many watts of solar power fall on the solar panel if the solar panel is
         25 per cent efficient.   2 marks

_____

_____

b.   Calculate the average amount of solar energy collected per day in winter.   1 mark

_____

_____

c.   Is a 200 W solar panel large enough to keep the lawnmower's battery charged so that the field
         can be mowed once a week? Justify your answer.   2 marks

_____

_____

_____

Question 19 (5 marks)

The power output of the solar panel is measured at various times for one day. The results are shown below.
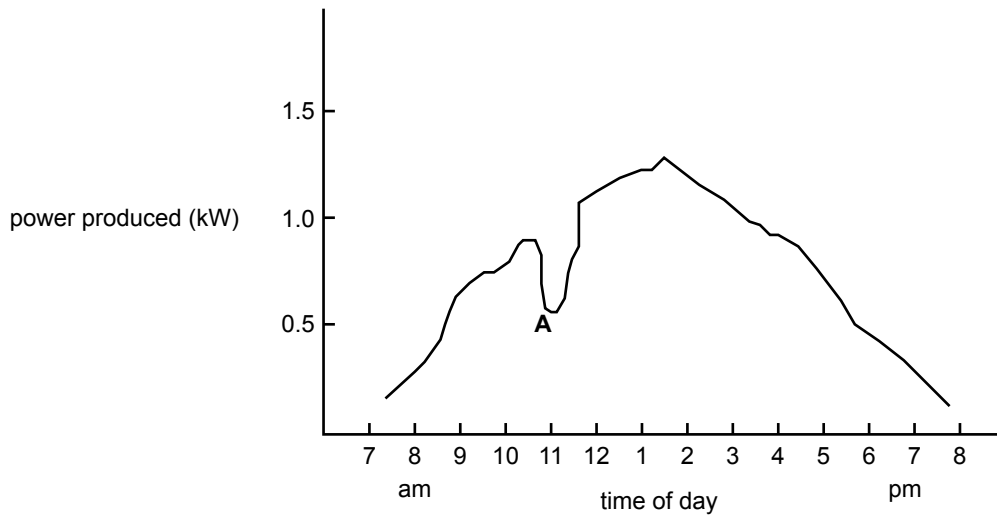
a. At what time of day is the output at maximum value? 1 mark

_____

b. Give a possible explanation for the shape of the graph at point A. 1 mark

_____

_____

c. The graph on page 22 shows the measurements of power output that were taken during a day in summer.

    i. On the axes below, sketch a likely shape for a graph based on results that would be obtained in winter.   1 mark

power produced (kW)

1.5 —

1.0 —

0.5 —

7   8   9   10 11 12 1   2   3   4   5   6   7   8
am   time of day   pm
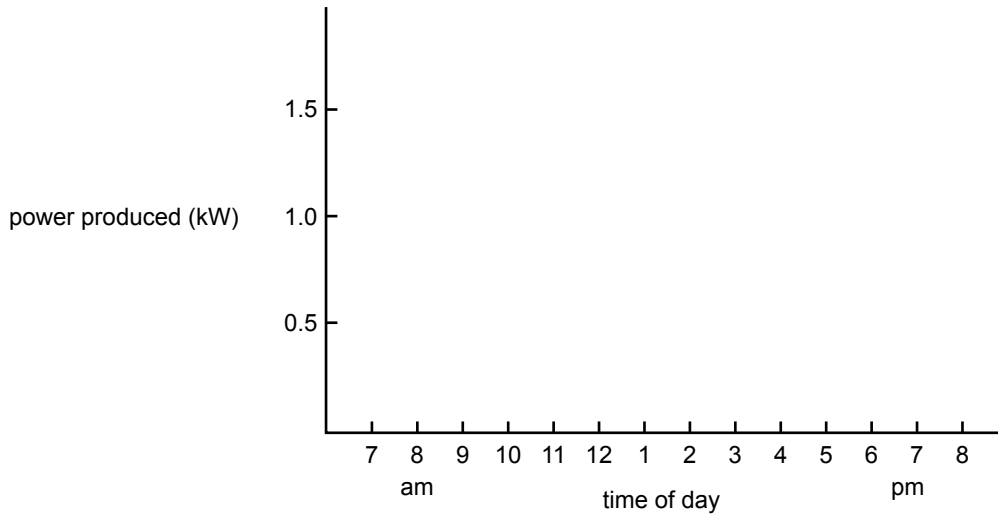
    ii. Justify the shape of the graph you have drawn.   2 marks

_____

_____

_____

Question 20 (3 marks)

The table below lists **some** of the processes in the construction of the robot lawnmower.

Produce a construction sequence for the production of the robot lawnmower using all of the processes listed.

The first process, 'identification of design features', has been entered as 1. Number the remaining processes from **2** to **9** to produce a feasible construction sequence for the robot lawnmower.

Some of the processes in the construction of the robot lawnmower	Construction sequence
identification of design features	1
construction of steering system	
computer simulation of electronics	
construction of frame	
mounting of wheels	
installation of metal wire in field	
mounting of sensors and microprocessor	
mounting of motor and gearbox	
simulation of motor and gearbox	

Question 21 (5 marks)

> **Autonomous cars**
>
> A variety of new technologies have been and are being introduced to make motor cars easier to operate and to improve road safety. Self-parking technology is already commercially available on several new car models sold in Australia. Another new technology available in new cars is a lane-change warning system. These two systems utilise proximity or distance sensors and computer vision for operation.
>
> Autonomous cars, or self-driving cars, are now being developed by major computer and car manufacturers overseas. Autonomous cars have the ability to self-drive safely on roadways by sensing the route, road conditions, other traffic, signage and obstacles. The control systems drive the car by controlling steering, braking, speed and proximity to other vehicles.
>
> Prototype autonomous cars currently utilise radar, proximity sensors, global positioning system (GPS) technology and computer vision to sense and guide the car. Working autonomous cars have been tested in the United States (US) and three US states have passed laws allowing the operation of autonomous cars on public roads.

Discuss the advantages and disadvantages of implementing autonomous cars in Australia.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Formula sheet

Gear ratio final = gear ratio 1 × gear ratio 2

$$\text{Efficiency} = \frac{\text{output energy}}{\text{input energy}} \times 100\%$$

Voltage = current × resistance

$$\text{Resistors in parallel: } R_t = \frac{R_1 \times R_2}{R_1 + R_2}$$

Colour codes

Colour	Value
black	0
brown	1
red	2
orange	3
yellow	4
green	5
blue	6
violet	7
grey	8
white	9
gold	5%
silver	10%

Resistors in series: $R_t = R_1 + R_2$

Power = voltage × current

Area of circle = πr^2 (π = 3.14)

Circumference of circle = $2\pi r$

Force = pressure × area

$$\frac{\text{gear A rpm}}{\text{gear B rpm}} = \frac{\text{number of teeth gear B}}{\text{number of teeth gear A}}$$

$$\frac{\text{pulley A rpm}}{\text{pulley B rpm}} = \frac{\text{radius of pulley B}}{\text{radius of pulley A}}$$

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{Gear ratio} = \frac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}}$$

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

Torque = force × distance

$$\text{Frequency} = \frac{1}{\text{period}}$$

$$\text{Efficiency}_{Total} = \text{Efficiency}_1 \times \text{Efficiency}_2$$

END OF QUESTION AND ANSWER BOOK