VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2015

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER | | | | | | | | | Letter |

SYSTEMS ENGINEERING

Written examination

Monday 16 November 2015

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	33	33	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 correction fluid/tape.

Materials supplied
- Question and answer book of 23 pages, including formulas on page 23.
- 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.

SECTION A – Multiple-choice questions

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.
Choose the response that is **correct** for the question.
A correct answer scores 1, an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless indicated, diagrams are not to scale.

Question 1

A 'danger' or 'unsafe' tag on an electrical device may be removed only by

A. a careful person who needs to use the electrical device.
B. someone with good electrical knowledge.
C. a technology teacher.
D. an electrician.

Question 2

What type of energy comes from heated groundwater?

A. hydro-electric
B. geothermal
C. biomass
D. solar

Question 3

Once an electromechanical system has been built, the next step in the Systems Engineering Process is to

A. test and diagnose.
B. evaluate and report.
C. start a brand-new project.
D. re-evaluate, modify and document.

Question 4

Which one of the following devices does not use magnetic fields for its operation?

A. relay
B. solenoid
C. transistor
D. transformer

Question 5

The thread pitch of a bolt is 1 mm. The bolt is tightened one half of a turn, or 180 degrees, after first contact with the parts to be fastened.

How much stretch has been applied to the bolt shank?

A. 2.0 mm

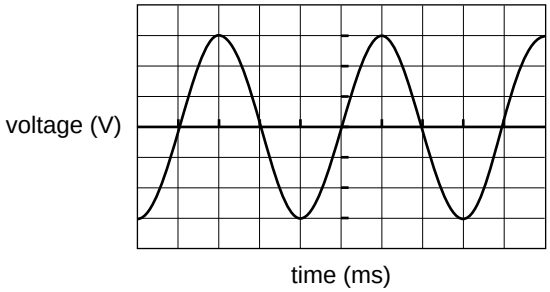
B. 1.5 mm

C. 1.0 mm

D. 0.5 mm

Use the following information to answer Questions 6 and 7.

The following diagram shows how voltage varies with time.



Question 6

Given that the voltage setting is 3 V per division, the peak-to-peak voltage is

A. 3 V

B. 6 V

C. 9 V

D. 18 V

Question 7

Given that the time setting is 1 ms per division, the frequency of the signal is

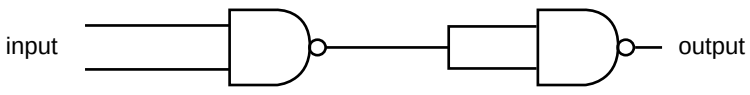
A. 250.00 Hz

B. 4.00 kHz

C. 4.00 Hz

D. 0.25 Hz

Question 8



Which one of the following logic gates can replace the two logic gates shown above?

A. OR

B. NOR

C. AND

D. NAND

Question 9

A solar panel has an efficiency of 30% and its battery has an efficiency of 90%.

What is the combined efficiency of this system?

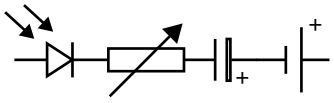
A. 12%

B. 27%

C. 30%

D. 60%

Question 10



Starting from the left, what are the names of the electrical components shown in the diagram above?

A. variable resistor, photo diode, capacitor, cell

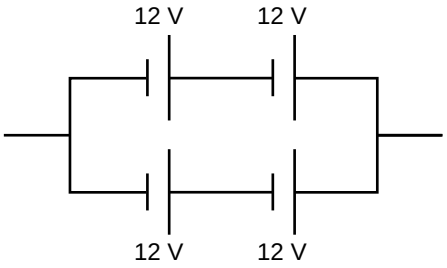
B. variable resistor, photo diode, cell, capacitor

C. photo diode, variable resistor, capacitor, cell

D. photo diode, variable resistor, cell, capacitor

Use the following information to answer Questions 11 and 12.

Four 12 V batteries, rated each at 4 Ah, are placed in an arrangement as shown below.



Question 11

The voltage output of this arrangement of batteries is

A. 6 V

B. 12 V

C. 24 V

D. 48 V

Question 12

How many hours would the batteries be likely to last if the arrangement was used to power a device rated at 96 W?

A. 1

B. 2

C. 4

D. 8

Question 13

The main role of occupational health and safety (OH&S) guidelines in a workshop is to provide

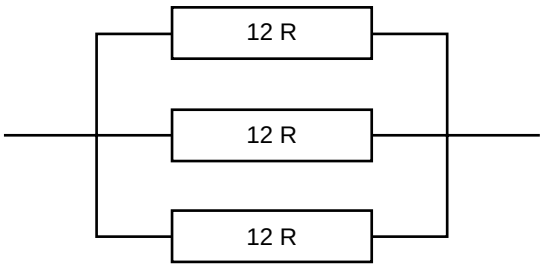
A. rules that users of the workshop must comply with.
B. instructions for the operation of all equipment.
C. rules for the protection of the teacher.
D. recommendations to all users.

Question 14

Fire extinguishers used to put out electrical fires work by removing

A. oxygen.
B. hydrogen.
C. carbon dioxide.
D. carbon monoxide.

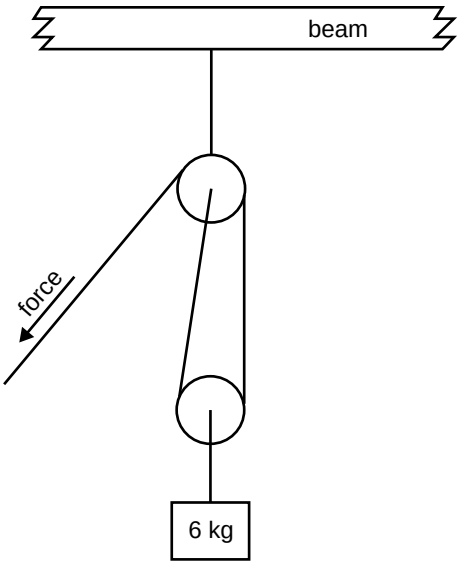
Question 15



The total resistance of the three-resistor arrangement shown above is

A. 3 Ω
B. 4 Ω
C. 6 Ω
D. 36 Ω

Question 16



The diagram above shows a pulley system with a 6 kg mass attached.

Ignoring the mass of the lower pulley and taking the gravitational constant to be $g = 10$ m s^{-2}, the minimum force needed to keep the 6 kg mass in equilibrium is

A. 2 N

B. 20 N

C. 30 N

D. 60 N

Question 17

How should a hacksaw be used safely and accurately when cutting a thick metal rod?

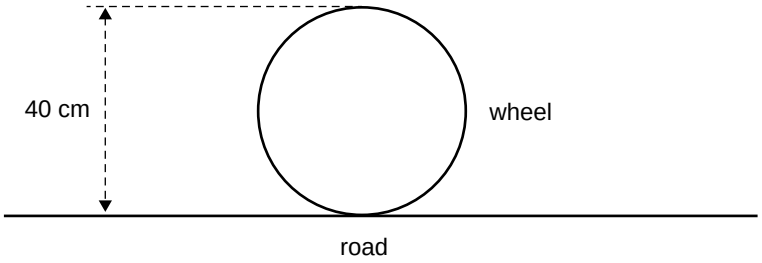
A. Hold the hacksaw with one hand and the rod with the other hand.

B. Apply pressure only on the forward stroke and clamp the rod.

C. Make sure that the teeth face the handle.

D. Cut in an upward direction.

Question 18



The wheel shown above has 200 N m of torque and a 40 cm diameter.
If we assume full contact and no slippage, the force of the wheel on the road is

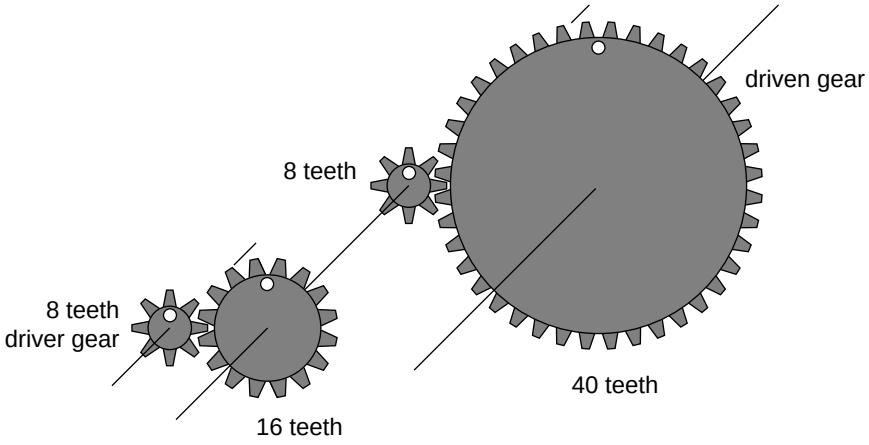
A. 5 N
B. 10 N
C. 500 N
D. 1000 N

Question 19

A speed of 2.592 m s^{-1} expressed to two significant figures is

A. 2.5
B. 2.59
C. 2.6
D. 2.60

Question 20



The gear ratio of the compound gear train shown above is

A. 1:5
B. 1:10
C. 5:1
D. 10:1

END OF SECTION A
TURN OVER

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 1–31.

One of the first lathes was designed by Leonardo da Vinci in the early 1500s. A simplified representation of his lathe is shown in Figure 1.

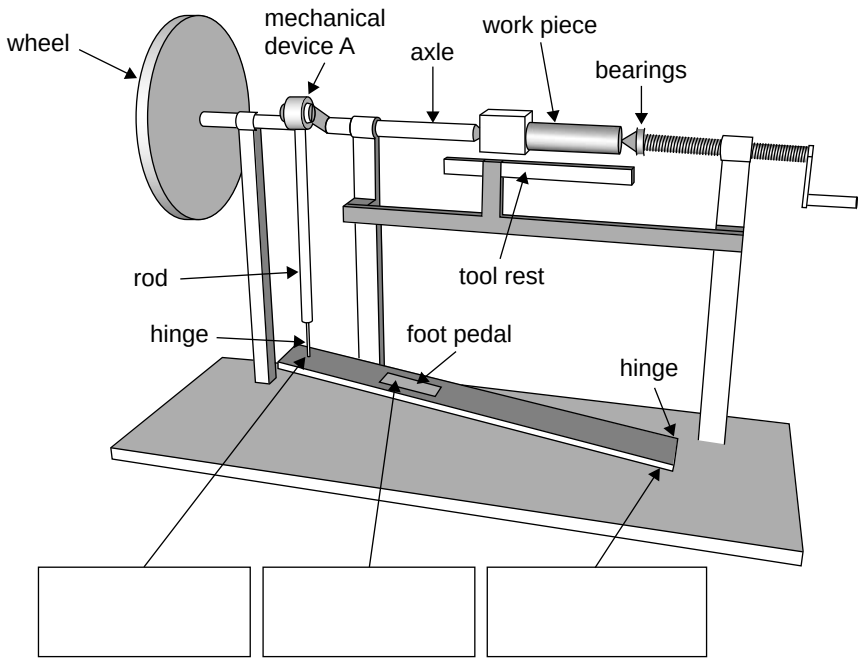


Figure 1

Question 1 (3 marks)

In the boxes provided in Figure 1, label the effort, fulcrum and load of the foot pedal.

Question 2 (1 mark)

What is the purpose of the wheel in the design shown in Figure 1?

_____

Question 3 (2 marks)

State the type of motion of each of the following.

- Wheel _____
- Foot pedal _____

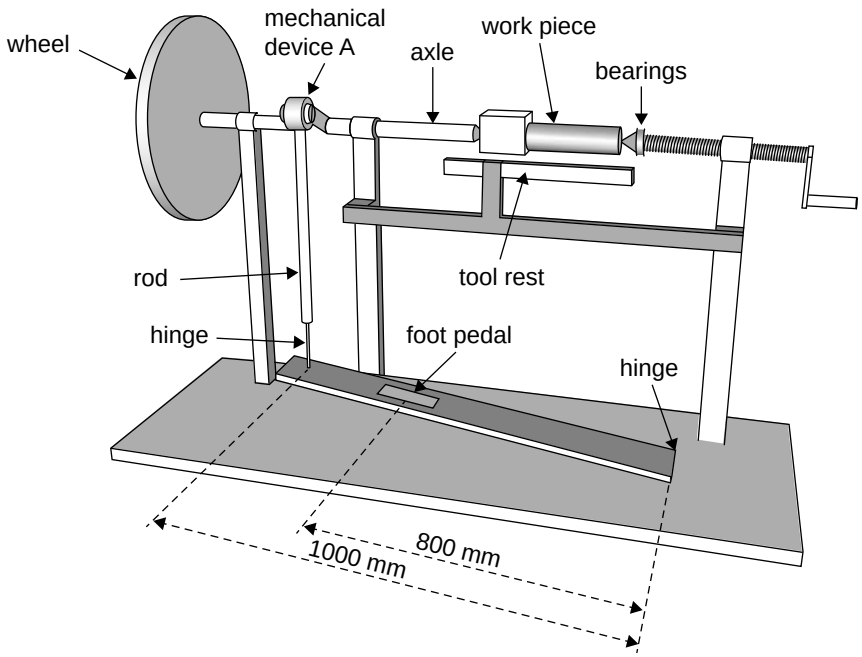


Figure 2

Question 4 (1 mark)

Name the device labelled 'mechanical device A' in Figure 2.

_____

Question 5 (4 marks)

a. Calculate the maximum force on the rod if the force of a foot on the pedal in Figure 2 is 100 N. Show your working. 2 marks

_____

_____

N

b. Calculate the mechanical advantage of the pedal system shown in Figure 2. Show your working. 2 marks

_____

_____

During the late 1800s, steam engines were used to drive industrial lathes and other equipment, as shown in Figure 3 below.

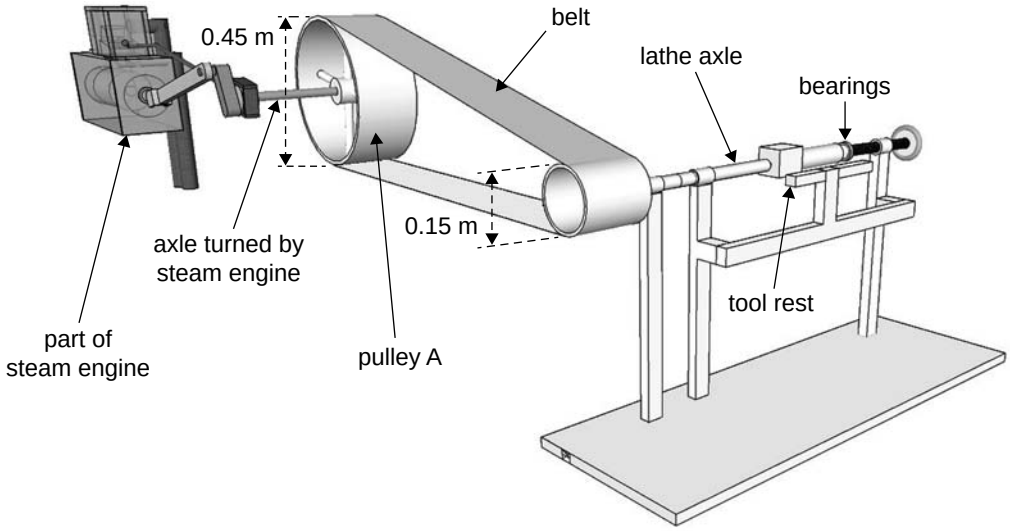


Figure 3

Pulley A is rotating at 300 revolutions per minute (rpm).

Question 6 (5 marks)

a. Calculate the rpm of the lathe axle in Figure 3. Show your working. 2 marks

rpm

b. Convert 300 rpm to revolutions per second (rps). 1 mark

rps

c. Calculate the speed of the belt in Figure 3. Show your working. 2 marks

m s^{-1}

Question 7 (1 mark)

Given that the steam engine always rotates in the same direction, how could a belt-and-pulley system be modified to reverse the direction of the lathe axle?

Question 8 (1 mark)

Give **one** essential piece of personal safety equipment that must be used when operating a lathe.

In a different set-up of the steam engine, a gearbox with a gear ratio of 1:4 is used.

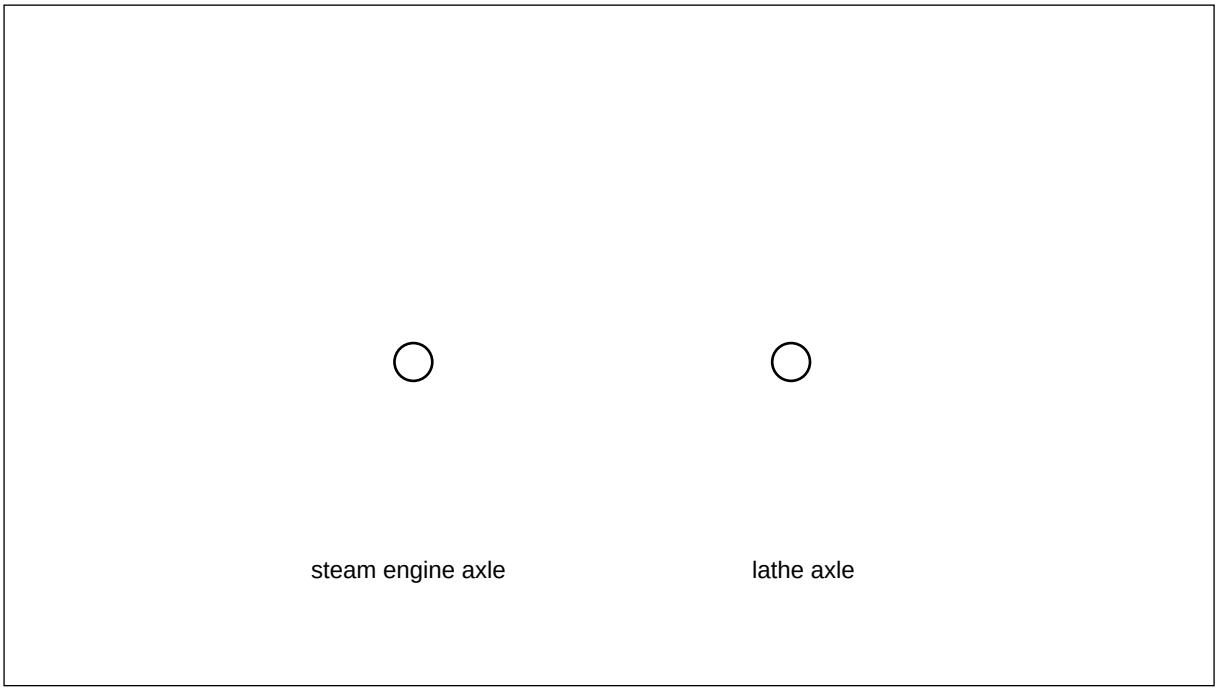
Question 9 (4 marks)

Draw and label the components of the gearbox, given that the steam engine axle and the lathe axle rotate in the same direction. Use **either** the end view **or** the top view diagram provided below for your answer.

Only spur gears from the following range of sizes (number of teeth) may be used:

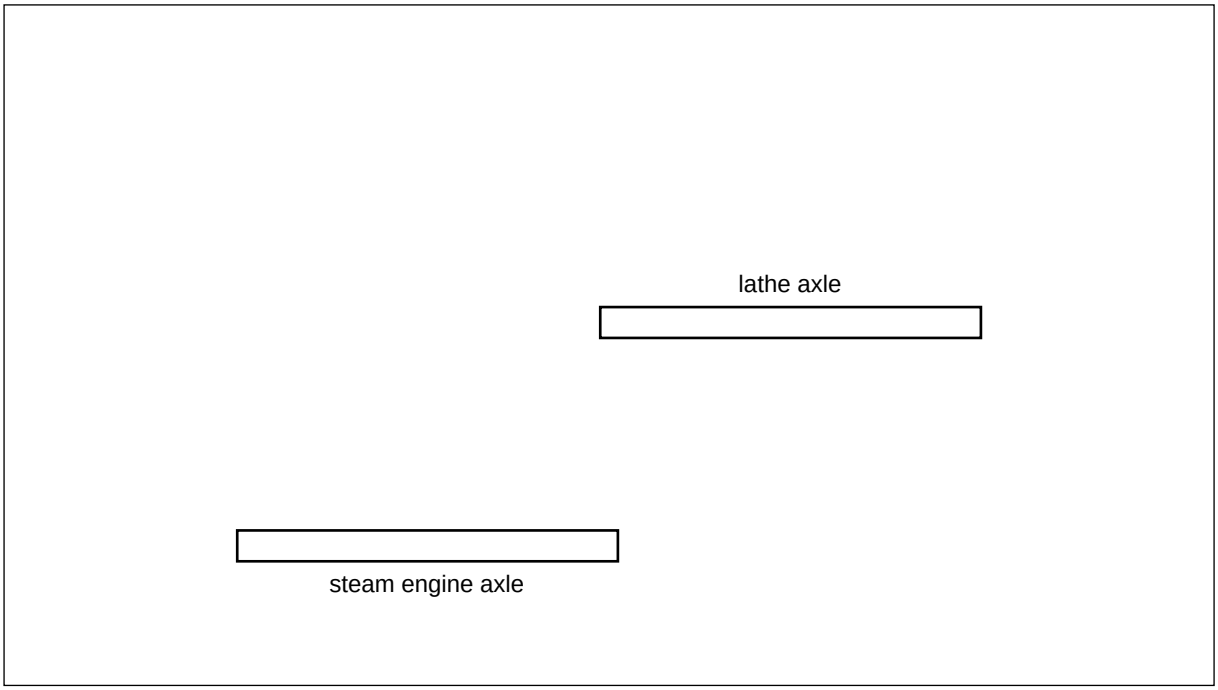
10 teeth 20 teeth 30 teeth 40 teeth 50 teeth

End view



OR

Top view



CONTINUES OVER PAGE

Question 10 (2 marks)

a. State **one** advantage of using a pulley system rather than a gearbox. 1 mark

b. State **one** disadvantage with respect to safety when using a pulley system rather than a gearbox. 1 mark

Question 11 (2 marks)

Describe how test equipment can be used to measure the rpm of a slowly rotating axle of a steam engine.

The steam engine shown in Figure 4 works by having steam forced into either side of the piston by an oscillating rod. The pressure of the steam going into the piston is 10 kPa.

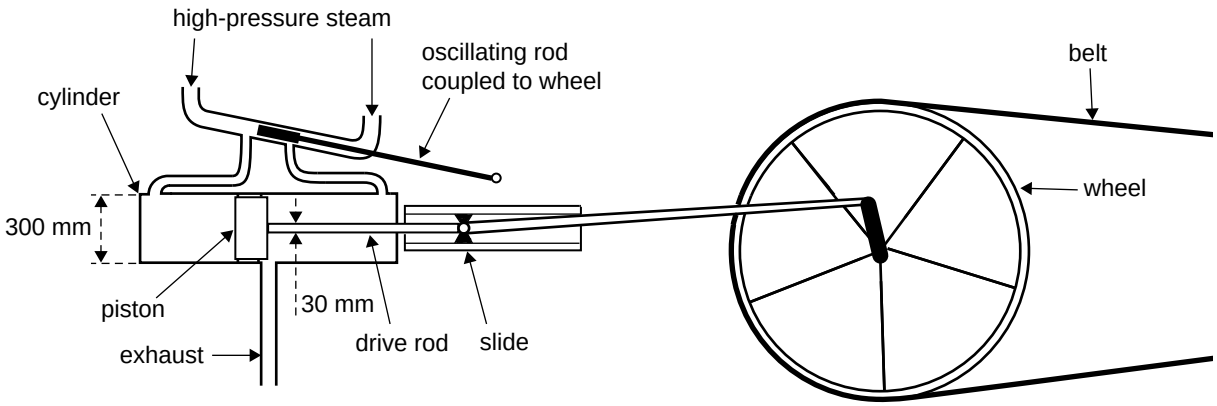


Figure 4

As the axle of the steam engine rotates, steam is forced into the left-hand side of the cylinder, then the right-hand side of the cylinder.

Question 12 (1 mark)

Using the information in Figure 4, in what direction is the wheel rotating?

Question 13 (3 marks)

Calculate the force on the piston in Figure 4 as steam enters the left-hand side of the cylinder.

N

Question 14 (1 mark)

Why is the force on the piston in Figure 4 greater when the piston moves to the right compared to when the piston moves to the left?

Question 15 (4 marks)

a. State two environmental issues that should be considered when using a wood-fired steam engine to power a lathe. 2 marks

1.

2.

b. State two environmental issues that should be considered when using mains electricity to power a lathe. 2 marks

1.

2.

Question 16 (3 marks)

State the type of energy present in each of the following.

- Dry wood
- Steam
- Spinning wheel

Question 17 (2 marks)

Instead of a steam engine powering a lathe, an electric motor can be used. The electric motor has an electric power rating of 1.2 kW with an input of 240 VAC mains electricity.

Calculate the current through the motor. Show your working.

A

In a different design, a 12 V_{DC} motor and an electronic speed controller are used. The circuit diagram for the speed controller is given in Figure 5 below.

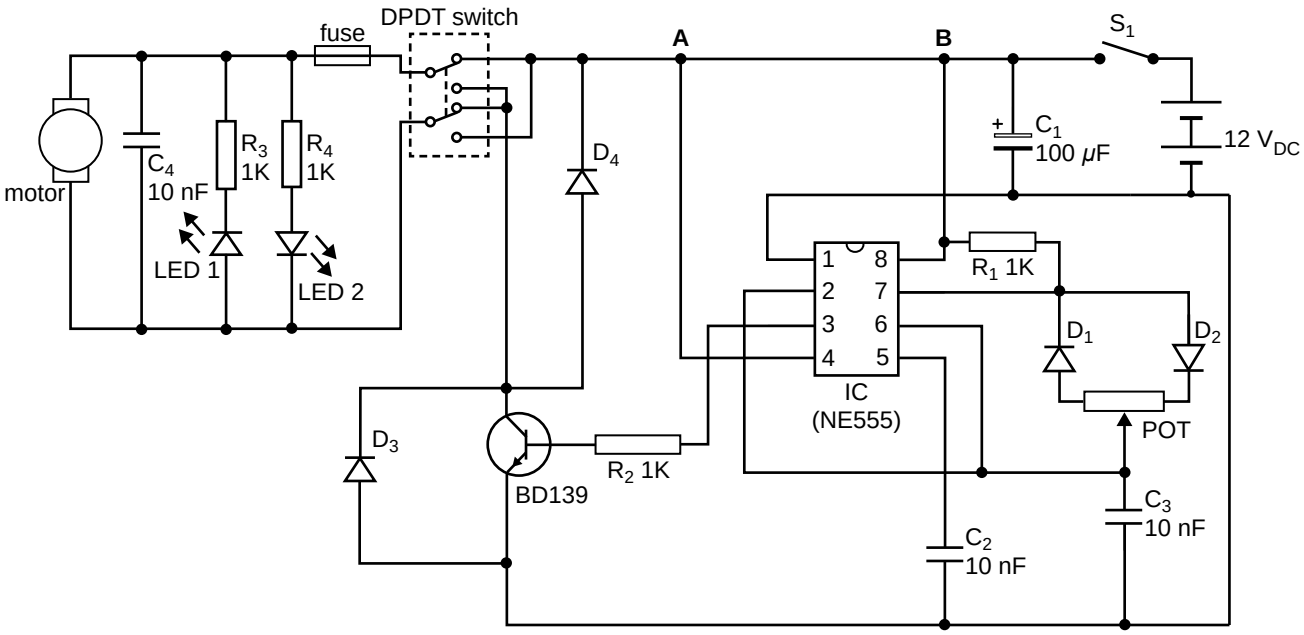


Figure 5

Question 18 (1 mark)

On Figure 5 above, draw an arrow between points A and B to show the direction of the conventional electric current when switch S_1 is closed.

Question 19 (4 marks)
Referring to Figure 5, what do the following stand for?

- LED _____
- IC _____
- POT _____
- μF _____

Question 20 (1 mark)
What is the function of the DPDT switch shown in Figure 5?

_____

Question 21 (1 mark)
Referring to Figure 5, resistor R_1 has four colour bands with a tolerance of 5%.

Write down the colour bands of R_1.

_____

Question 22 (2 marks)
Referring to Figure 5, calculate the voltage across resistor R_3 if the electric current through LED 1 is 10 mA.

_____

_____

V

Question 23 (1 mark)
What is the purpose of LED 1 and LED 2 shown in Figure 5?

_____

_____

Question 24 (2 marks)

A digital multimeter set on DC volts is used to measure the voltage across two selected pins of the IC shown in Figure 5.

State the value expected for each of the following selected pairs of pins as the motor operates.

- 1 and 8 ____ V
- 2 and 6 ____ V

Question 25 (4 marks)

a. Referring to Figure 5, if LED 1 was not working, what would be two possible faults, apart from the LED being faulty? 2 marks

1. _____

2. _____

b. Give two possible consequences if C_4 was short circuited in Figure 5. 2 marks

1. _____

_____

2. _____

_____

Question 26 (3 marks)

During testing, capacitor C_1 is found to be faulty and needs to be replaced. There are only 50 μF or 200 μF capacitors available.

How could 50 μF or 200 μF capacitors be used to take the place of the 100 μF capacitor in Figure 5? Draw a circuit diagram and justify your choice by showing appropriate calculations.

_____

_____

_____

Question 27 (3 marks)

What is one function of each of the following components in an electric circuit?

- Diode _____
- Transistor _____
- Capacitor _____

The section of the circuit between the motor and the DPDT switch is to be on a separate circuit board, as shown in Figure 6.

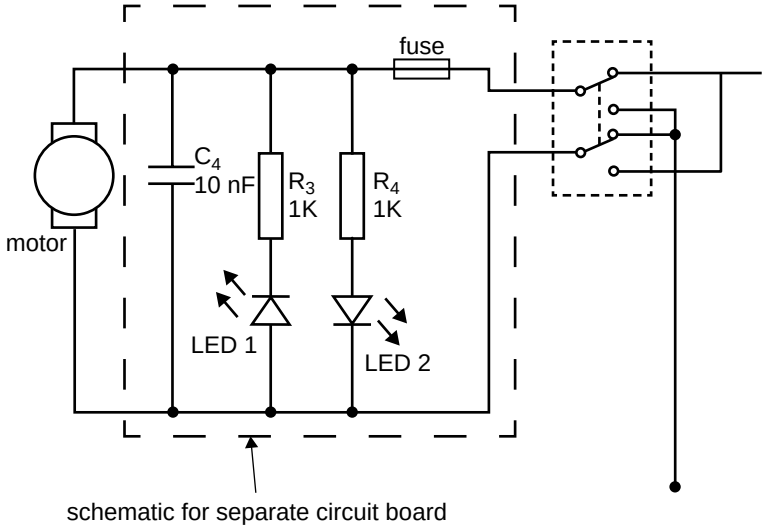
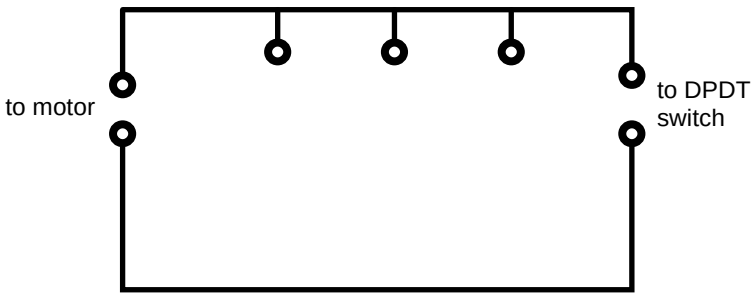


Figure 6

Question 28 (3 marks)

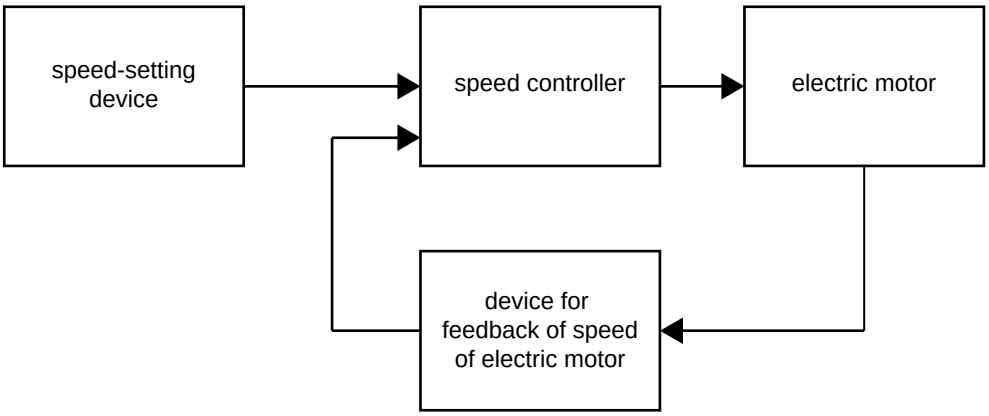
Complete the design for a circuit board for the section of circuit shown in Figure 6. Indicate the position of C_4, R_3, R_4, LED 1 and LED 2 on the diagram provided below.



The lathe will be used to turn wood with a maximum length of 90 cm and a diameter of 25 cm, and will have a revolution range of 800–4800 rpm.

In order to control the speed of rotation of the lathe axle, a speed controller and a brushless electric motor are used.

A systems diagram is shown below.



Question 29 (1 mark)

Why would the system be considered a closed-loop system?

A graph of the speed of rotation and the voltage across the electric motor is given in Figure 7.

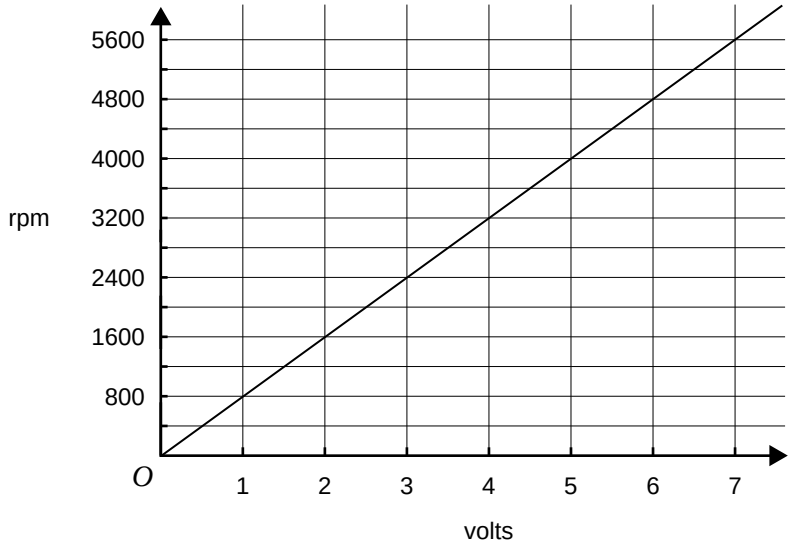


Figure 7

Question 30 (3 marks)

a. Using the graph in Figure 7, give the voltage required for an rpm of 4000. 1 mark

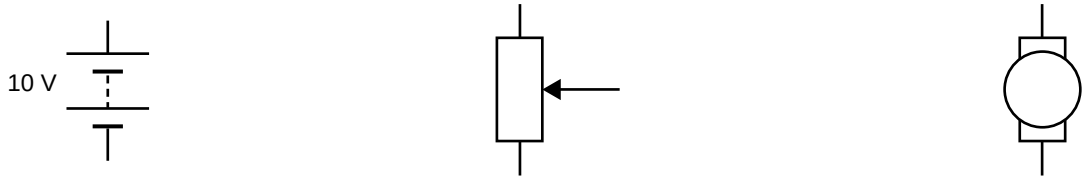
V

b. Referring to Figure 7, state the minimum and maximum voltages for the motor to operate at the range of rpm required. 2 marks

Minimum V Maximum V

Question 31 (2 marks)

Complete the circuit diagram below to design a circuit that would supply the motor with a variable voltage.



Question 32 (4 marks)

The following is a list of terms connected to the Systems Engineering Process:

materials list	flow diagrams	design brief
costs	make adjustments	draw conclusions

For each of the four boxes below, select and fill in the correct term for that step of the Systems Engineering Process. Each term may only be used once.

identify and document problem/need/ opportunity/situation _____	research feasibility and alternatives _____	design and model the system _____	plan, build and fabricate/integrate subsystems _____

Question 33 (5 marks)

Robots controlled by automated systems technology are used in many areas of medicine, including surgery. Robot-assisted surgery is relatively common and is conducted by a doctor who controls the robot while in the same location as the surgery.

Less common is the use of robots for remote surgery, where a doctor who is not physically present is still able to perform surgery on a patient through the use of a robot and advanced communications technologies. In such a situation, the doctor would command the robot from a different location through the use of communications technologies, such as a high-speed data transfer program.

Discuss the issues and the consequences that may arise relating to the use of robot-assisted surgery and remote surgery. In your response, you should include:

- at least **three** major issues
- the advantages and disadvantages of using automated systems technology.

END OF SECTION B

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 ($\pi = 3.14$)

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

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

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

capacitors in parallel: $C_t = C_1 + C_2$

$$\text{capacitors in series: } \frac{1}{C_t} = \frac{1}{C_1} + \frac{1}{C_2}$$

END OF QUESTION AND ANSWER BOOK