Rewarding Learning

ADVANCED
General Certificate of Education
2014

Technology and Design

Assessment Unit A2 1

assessing

Systems and Control

[AV211]

AV211

WEDNESDAY 14 MAY, MORNING

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number on the Answer Booklet provided and on the A3 pro forma answer pages provided.
Answer **either** the **two** questions in Section A **or** the **two** questions in Section B **or** the **two** questions in Section C.
Answers to Questions **1(e)(ii)**, **2(d)**, **3(d)(i)**, **3(d)(ii)**, **3(e)(i)** and **(ii)**, **4(c)**, **4(d)(i)** and **(ii)**, **5(g)(i)** and **(ii)** and **6(g)(i)** and **(ii)** should be made on the A3 pro forma answer pages provided.
At the conclusion of the examination, attach the A3 pro forma answer pages securely to the Answer Booklet with the treasury tag supplied.

INFORMATION FOR CANDIDATES

The total mark for this paper is 80, including a maximum of 4 marks for quality of written communication.
Marks for quality of written communication will be awarded for Questions **2(e)**, **3(c)** and **5(e)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

Answer **either** the **two** questions in Section A or the **two** questions in Section B or Section C.

Section A

Electronic/Microelectronic Systems

1 A block diagram for a gas pressure display system is shown in **Fig. 1(a)**.

The signal from the pressure sensor is amplified and displayed on a meter. The output from the amplifier is also used to control a solenoid valve by means of a PIC.

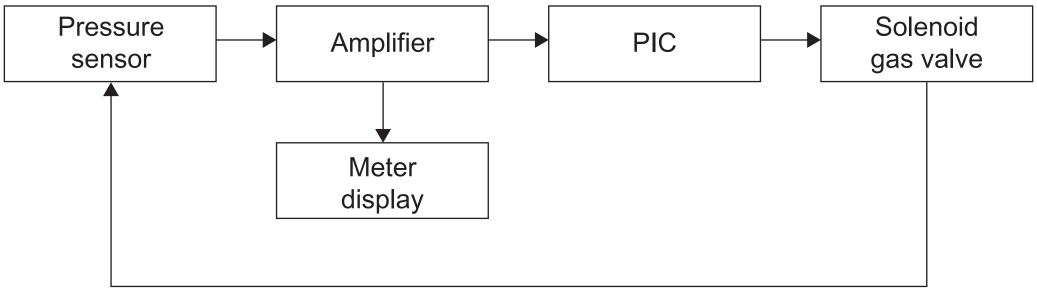


Fig. 1(a)

(a) **(i)** State if the system shown in **Fig. 1(a)** could be considered open loop or closed loop and briefly justify your answer. [2]

(ii) For any **three** blocks of your choice in the diagram shown in **Fig. 1(a)** state whether each is input, control or output. [3]

(b) **Fig. 1(b)** shows the gas pressure sensor which consists of a sliding type 100 kΩ linear variable resistor connected to a power supply. The voltage, Vo, is measured between the sliding wiper at terminal B and terminal C. The wiper which can move a total distance of 25 mm from A to C is linked to the gas pressure cell. Small changes in gas pressure cause the cell to expand or contract which moves the sliding wiper of the variable resistor using a linkage.

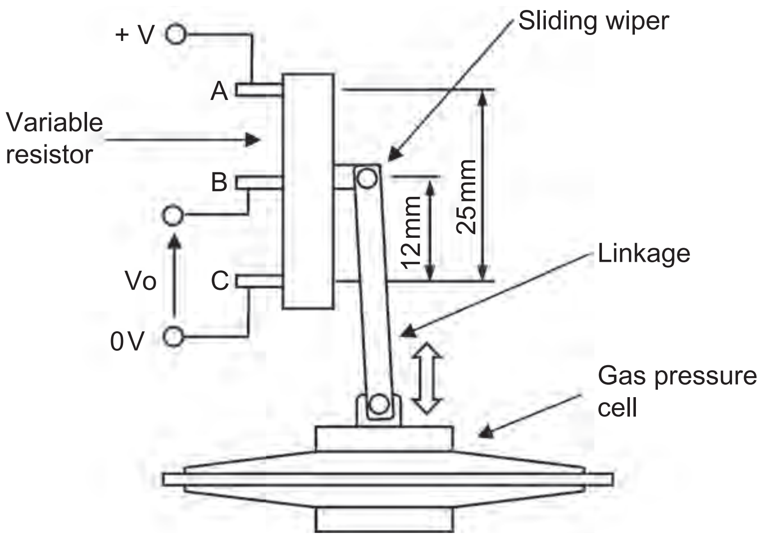


Fig. 1(b)

(i) Sketch a graph with labelled axes showing how the voltage Vo in **Fig. 1(b)** varies as the wiper is moved from terminal C towards terminal A. [2]

(ii) Calculate the resistance between terminals A and B when the wiper is in the position shown in **Fig. 1(b)**. [2]

(c) (i) The voltage Vo in **Fig. 1(b)** is to be displayed on a voltmeter which operates from 0 to 5 volts, as shown in **Fig. 1(c)**. The maximum movement of the sliding wiper of the variable resistor is 25 mm. This produces a change in Vo of 1 mV for every 0.05 mm moved. The maximum gas pressure displayed by the meter, in N/cm^2, should represent the maximum movement of the wiper of the variable resistor i.e. the meter should display from 0 N/cm^2 to 50 N/cm^2 when the wiper moves from 0 mm to 25 mm.

Determine the gain of an amplifier required to be connected between terminal B on the variable resistor and the meter to meet this requirement. [3]

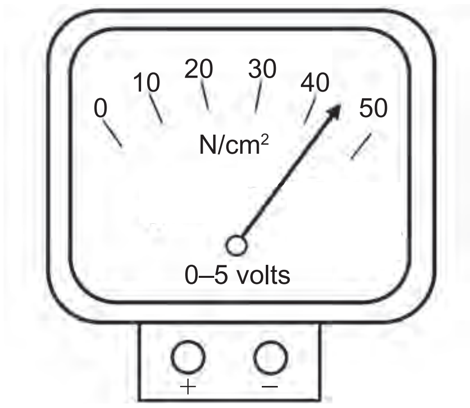


Fig. 1(c)

(ii) An amplifier based on an op amp is to be used for **(c)(i)** above where the gain of an inverting amplifier and a non-inverting amplifier is given by $-R_f/R_1$, and $1 + R_f/R_1$ respectively. Draw a suitable amplifier and specify suitable values for R_f and R_1, where R_f is the feedback resistor. [4]

(d) A PIC with an analogue input and a digital output is shown in **Fig. 1(d)** along with a 24 volt solenoid operated valve.

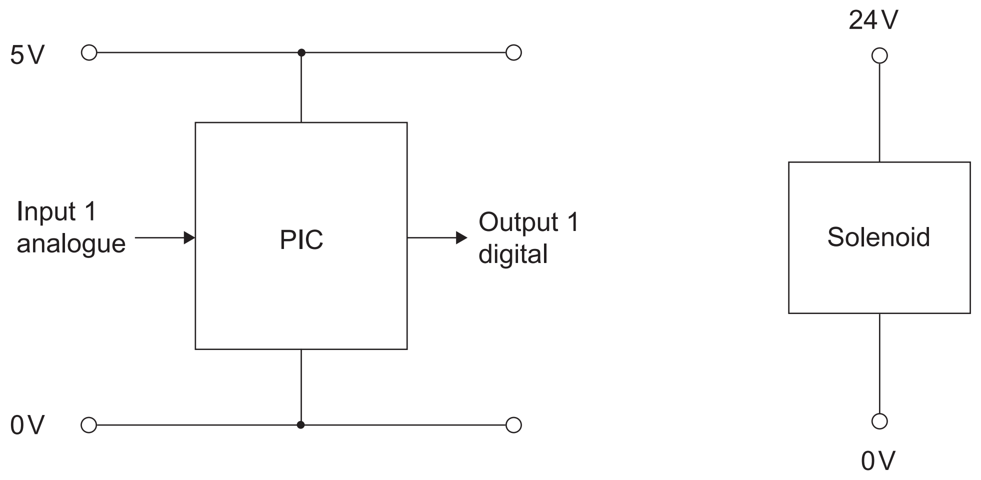


Fig. 1(d)

(i) Explain the purpose of an analogue input on a PIC. [2]

(ii) The voltage range of the analogue input to the PIC shown in **Fig. 1(d)** ranges from 0V to 3V and the corresponding digital range is 0 to 15. Determine the digital values for input voltages of 1.2 volts and 1.8 volts. [2]

(iii) With the aid of an annotated circuit diagram, show how the variable resistor shown in **Fig. 1(b)** could be connected to the input of the PIC shown in **Fig. 1(d)** in order to “read” Vo. In addition show how the output of the PIC shown in **Fig. 1(d)** could be connected to the solenoid shown in **Fig. 1(d)** to enable it to be switched on and off. [4]

(iv) Draw a flowchart that will check the analogue input (input 1) of the PIC every 5 seconds and switch the digital output (output 1) off if the input voltage is greater than 1.8V and switch the digital output on if voltage is less than 1.2V. [4]

(e) An alternative system is to be developed that utilises a strain gauge to detect the bending movement of the gas pressure cell in **Fig. 1(b)** and display this as a number on an eight segment LED bar graph display utilising a display driver. The strain gauge is shown in **Fig. 1(e)** and has an unstrained resistance of 120 Ω. For testing purposes it was attached to the gas pressure cell and the results of the test indicated that the resistance of the strain gauge increased by 2.5% under maximum test conditions.

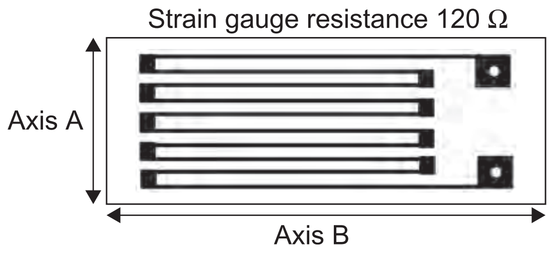


Fig. 1(e)

(i) Calculate the resistance of the strain gauge shown in **Fig. 1(e)** when under maximum test conditions. [2]

(ii) Using annotated electronic circuit diagrams (on the blank pro forma provided (**answer number 1(e)(ii)**) design a system that will:

- detect the bending movement of the gas pressure cell and display the representative pressure on an eight bar LED bar graph display.
- illuminate all eight bars of the bar graph display when the strain gauge is experiencing maximum test conditions as indicated above.
- include a means of temperature compensation.
- operate with a power supply of +6 volts and −6 volts.

Your answer should specify suitable component values where appropriate. [10]

2 **Fig. 2(a)** shows an incomplete circuit consisting of a 5 volt supply and two resistors, R1 and R2. The resistors are connected to an infra red LED and phototransistor respectively.

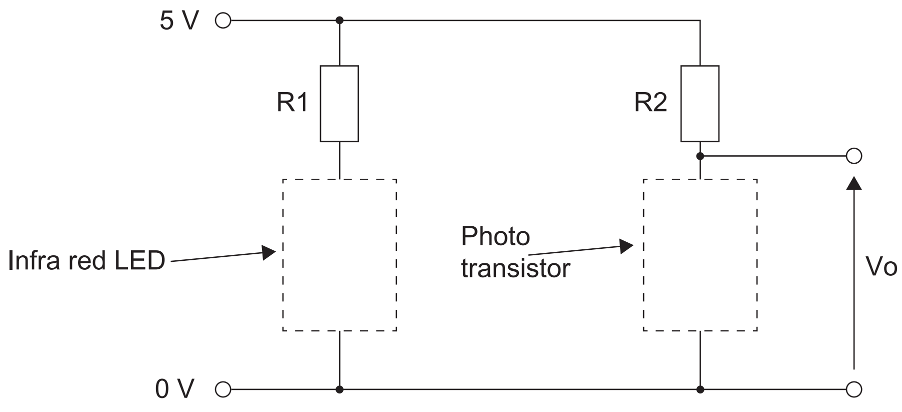


Fig. 2(a)

(a) **(i)** Draw the circuit symbols for an infra red LED and a phototransistor. [2]

(ii) With the aid of a labelled graph, explain how the voltage Vo in **Fig. 2(a)** changes when a solid object passes between the infra red LED and the phototransistor. [3]

(iii) Show, with the aid of a diagram, how the circuit shown in **Fig. 2(a)** could be modified to incorporate an LED that will illuminate to indicate when the phototransistor is conducting. [2]

(b) Part of a model for a bridge toll barrier is shown in **Fig. 2(b)**. A coin box used to operate a barrier is shown along with the proposed method of detecting the correct coin size when coins are rolled down a coin chute. Coins of three sizes are detected by three phototransistors (Ta, Tb and Tc) and corresponding infra red transmitters. The phototransistors are each situated so that they detect the top of each of the coins. Coins A and C are acceptable while coin B is not acceptable. A logic circuit will be used to control the Coin Accept (CA) and Coin Reject (CR) lights which illuminate accordingly.

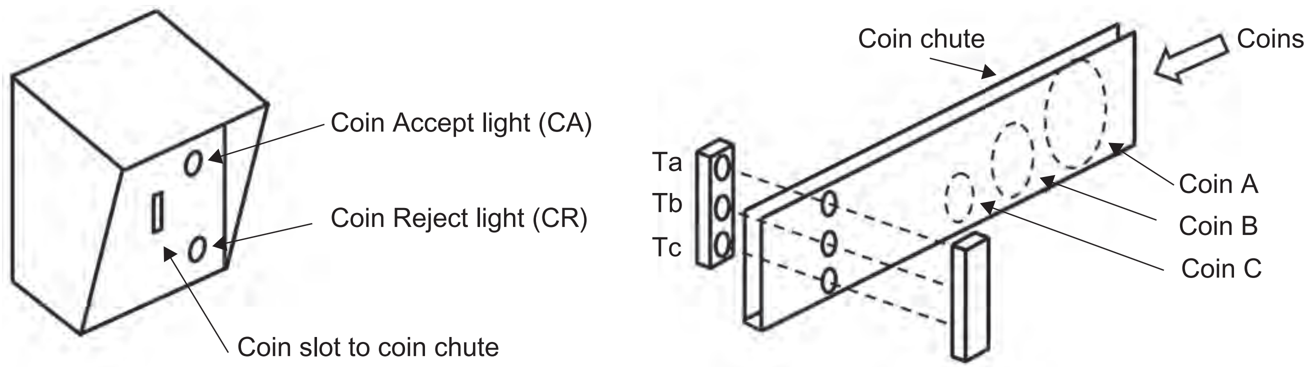


Fig. 2(b)

(i) Draw a truth table to represent the logic combinations for the phototransistors Ta, Tb and Tc which result in the corresponding Coin Accept (CA) and Coin Reject (CR) lights illuminating in **Fig. 2(b)**. Assume that each phototransistor produces a logic 1 when a coin is detected. [3]

(ii) Deduce logic expressions for CA and CR. [2]

(iii) Draw a suitable logic circuit for CA and CR. [3]

(c) A stepper motor driver is shown in **Fig. 2(c)**.

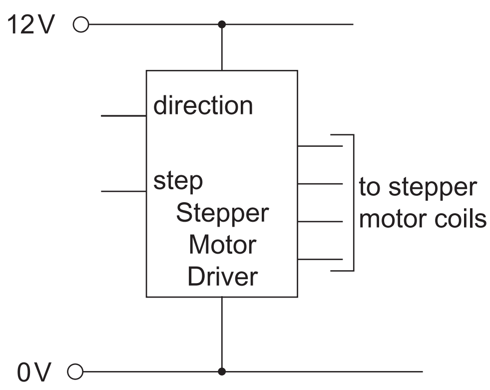


Fig. 2(c)

(i) State the function of the **step** input on the stepper motor driver shown in **Fig. 2(c)**. [1]

(ii) State **two** operational differences between a stepper motor and a DC motor. [2]

(iii) The stepper motor driver shown in **Fig. 2(c)** is to be used to control a stepper motor with a step angle of 7.5°. Calculate the frequency of the step input required to rotate the stepper motor through 90° in 3 seconds. [3]

(d) The coin box system shown in **Fig. 2(b)** is required to control a motorised barrier which is shown in **Fig. 2(d)** below.

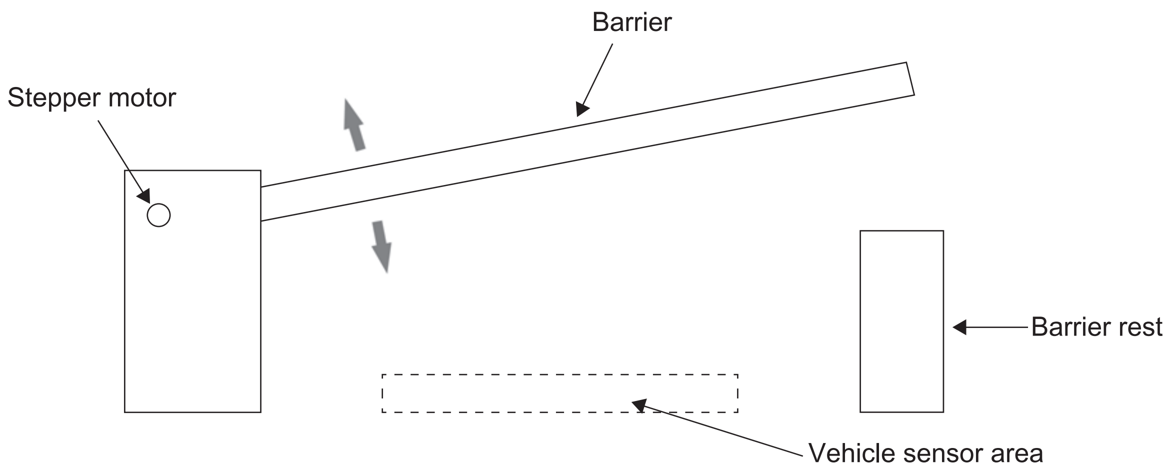


Fig. 2(d)

Using a PIC based circuit, with annotated circuit diagrams and associated flow chart, (on the blank pro forma provided (**answer number 2(d)**) design a system that will achieve the following:

- Utilise the logic signal from the coin accept light from question **2(b)** and the stepper motor from question **2(c)(iii)** so that when 3 coins of the correct size have been detected the barrier is raised by the stepper motor through 90° in a time of 3 seconds.
- After a time delay of 10 seconds the barrier should be lowered to its original position in a time of 6 seconds.
- A suitable sensor located underneath the barrier should prevent the barrier from lowering if a vehicle is detected. [10]

(e) It has been suggested that the bulb in the coin accept light utilised in the system shown in **Fig. 2(b)** could be replaced by an LED type display (such as single LEDs, seven segment displays or bar arrays) to provide a visual indication of the number of accepted coins. With reference to the application in **Fig. 2(b)**, discuss **two** main factors that would influence the choice of a particular type of LED display. Describe **three** characteristics of LED type displays that a designer can specify when considering a particular application. [5]

Quality of written communication [4]

Answer **either** the **two** questions in Section A or the **two** questions in Section B or Section C.

Section B

Mechanical and Pneumatic Control Systems

Answer **both** questions in this section.

3 **Fig. 3(a)** shows an image of a prototype crane that may be used to transport materials on a building site. The crane contains a range of mechanical and hydraulic components and is powered by a diesel engine.

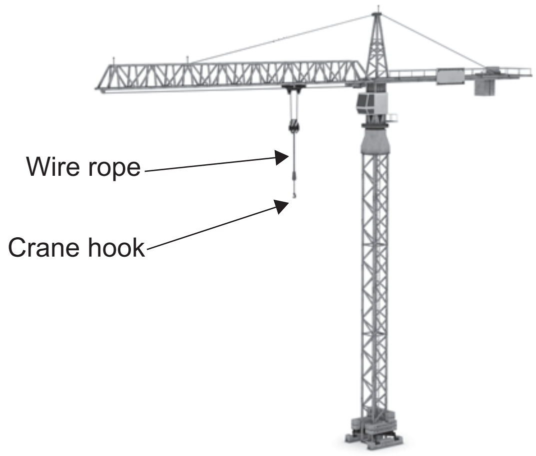


Fig. 3(a)

(a) The wire rope in **Fig. 3(a)** is fed through a four pulley block lifting system when the crane hook is raised and lowered. With the use of an annotated sketch draw a four pulley block lifting system. [3]

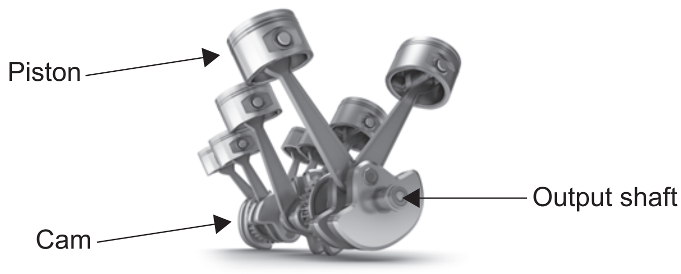


Fig. 3(b)

(b) **(i)** **Fig. 3(b)** shows an image of the piston, cam and output shaft for the diesel engine used in the crane. Calculate the minimum power required from the output shaft to lift the crane hook 20 metres in 120 seconds if the gravitational force on the hook is 18000 N. Assume a 20% loss of power due to friction. [2]

(ii) The piston shown in **Fig. 3(b)**, moves a total of 220 mm 2800 times per minute. If the piston has a mass of 0.5 kg, calculate the kinetic energy for the piston ignoring friction. [3]

(iii) Gaskets play a vital role in the engine of the crane. Give **two** main reasons why they are used. [2]

(iv) Static and dynamic friction occur in various moving parts of the crane. Describe the difference between static and dynamic friction. [2]

(c) Lubricants in the form of oil are widely used in a range of moving parts of the crane. Discuss **three** technical factors to be considered when selecting a lubricant for a particular application. Supplement your answer with **one** specific example with justification of choice of lubricant. [5]

Quality of written communication [4]

(d) **(i)** **Fig. 3(d)(i)** below shows a blank performance diagram which will be used for a cam profile. On the pro forma provided, (**answer number 3(d)(i)**) using an appropriate drawing technique, construct a performance diagram which would accurately produce the following motion:

- 0–120 Uniform Velocity Rise for 15 mm
- 120–210 Simple Harmonic Motion with a rise of 15 mm
- 210–270 Dwell
- 270–360 Uniform Velocity with a fall of 30 mm

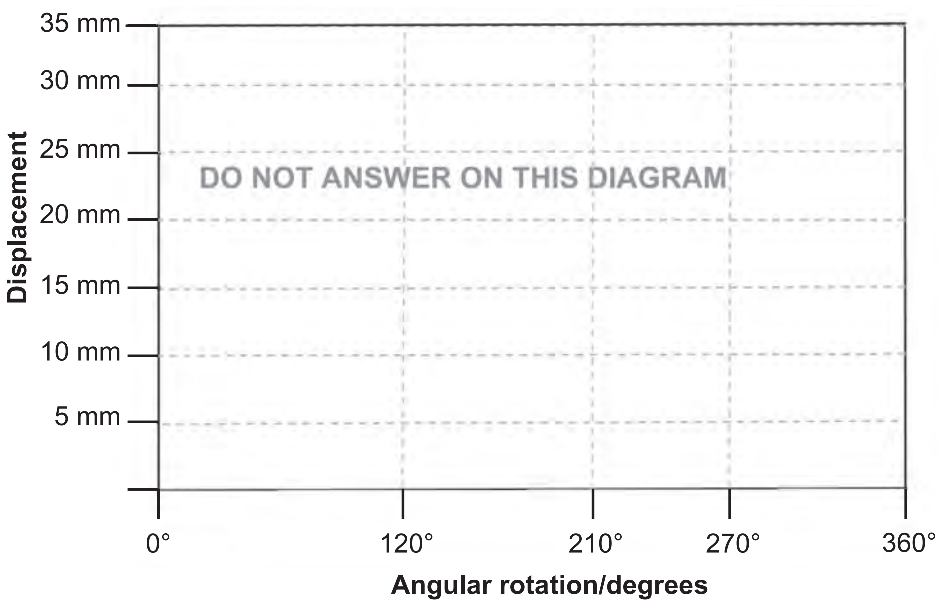


Fig. 3(d)(i) [4]

(ii) **Fig. 3(d)(ii)** below shows another performance diagram.

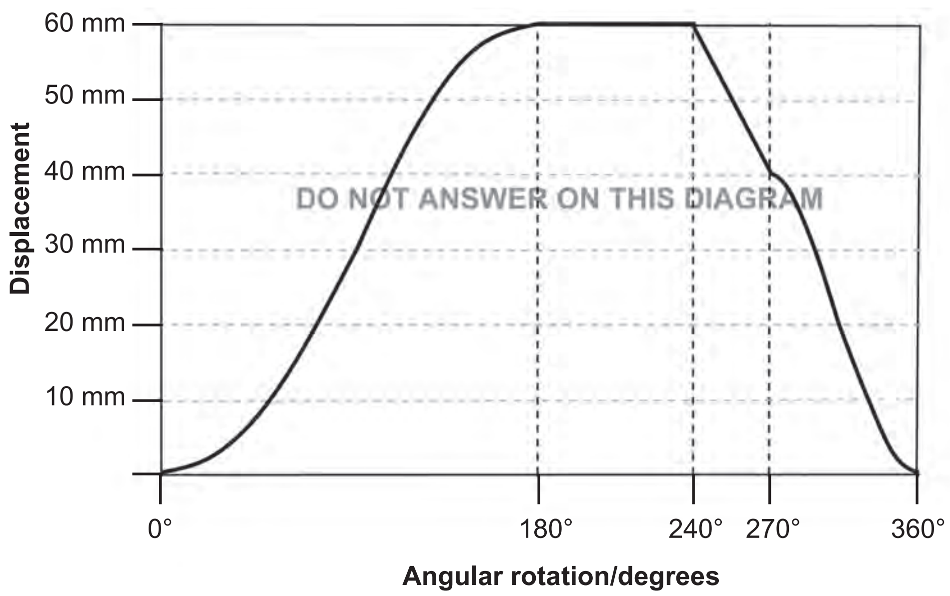


Fig. 3(d)(ii)

On the pro forma provided, (**answer number 3(d)(ii)**) using an appropriate drawing technique, construct a cam profile which would accurately follow the performance diagram. The minimum cam diameter is 40 mm. The follower is a roller follower with diameter of 20 mm and the cam rotates in an anti-clockwise direction. [5]

(e) **Fig. 3(e)(i)** and **(ii)** show two improvements required for the crane. On the blank pro forma provided, (**answer numbers 3(e)(i) and (ii)**), draw and annotate a mechanical system which would achieve each of the following requirements:

(i) In **Fig. 3(e)(i)** the operator needs a mechanism to suitably move the wipers on the crane cab. Design a means of connecting the motor output shaft to the wipers. This should allow the wipers to oscillate from the fixed point in an arc backwards and forwards while connected together. Your answer should show how the mechanism is attached to the motor shaft and any pivot points on the wipers. [4]

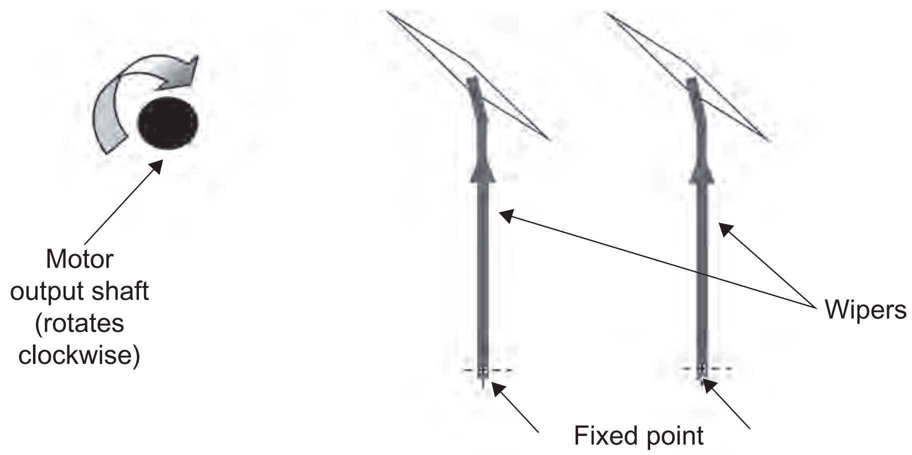


Fig. 3(e)(i)

(ii) **Fig. 3(e)(ii)** shows two views of the crane hook and shaft. Using the roller bearing shown, design a housing capable of holding both the bearing and shaft. Indicate how the bearing is secured in position and can be removed for maintenance. Also include provision for lubrication. [6]

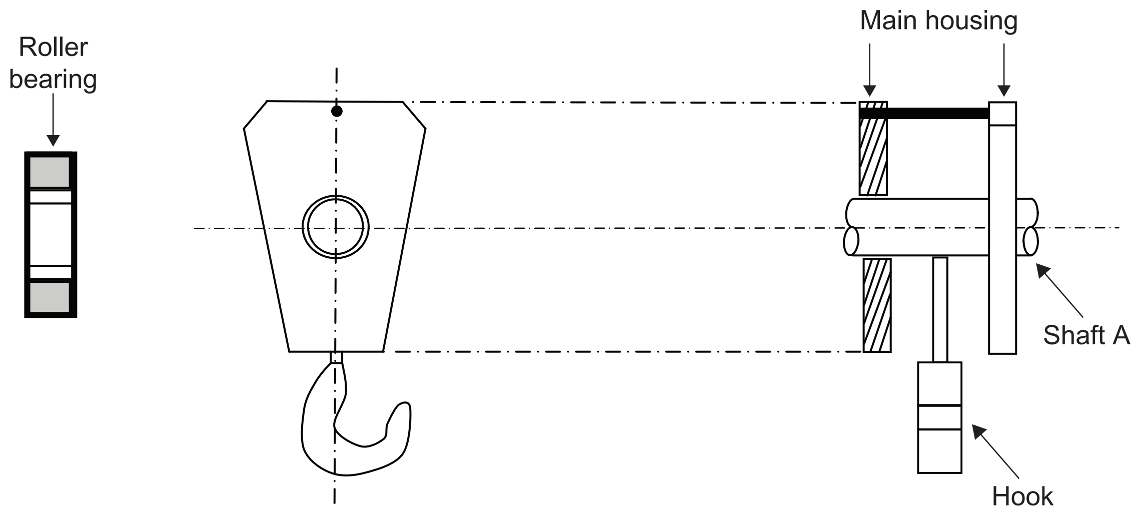


Fig. 3(e)(ii)

4 **(a)** When using air in pneumatic circuits safety is a key concern for the operator. Outline **one** safety procedure which should be adopted when using pneumatics. [1]

(b) **(i)** Explain how the circuit in **Fig. 4(b)(i)** operates; starting with activation of the air bleed (your answer should include a detailed explanation of the operation of valve B). [5]

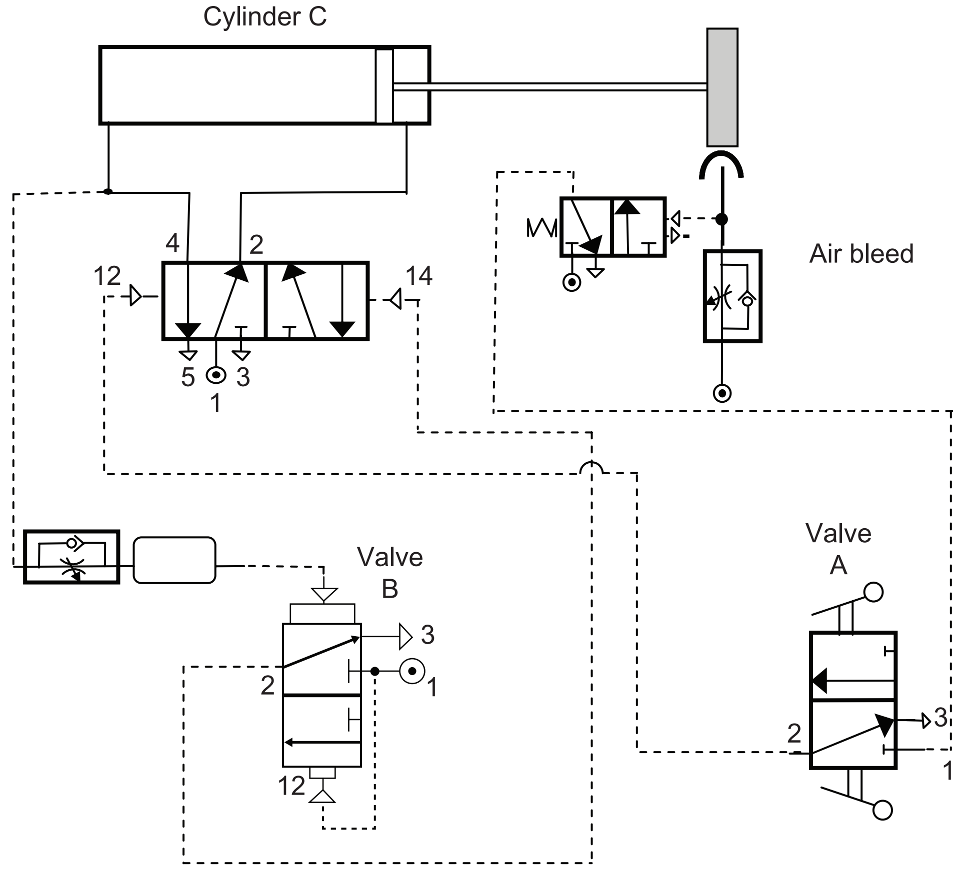


Fig. 4(b)(i)

(ii) Calculate the work done by cylinder C in **Fig. 4(b)(i)** if the force required to outstroke is 1098.3 N and the distance moved by the force is 600 mm. In your calculation ignore friction. [2]

(iii) With reference to **Fig. 4(b)(iii)** calculate the volume of air consumed by the cylinder as the piston rod moves through one cycle. Then calculate the maximum number of complete cycles that could be made by the piston rod per minute if the compressor has a capacity to produce 337.283 litres per minute.

D = 12 mm gauge pressure = 4 bar
d = 3 mm atmospheric pressure = 1.5 bar
S = 140 mm
(In your calculations ignore friction.) [4]

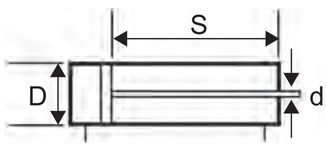


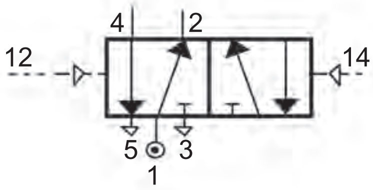
Fig. 4(b)(iii)

(c) On the pro forma provided, (**answer number 4(c)**) which shows a pneumatic hopper and conveyor system used in a quarry plant, draw a suitable sequential pneumatic circuit to achieve the desired sequence outlined. The sequence is as follows:

- Activation of the 3PV and 5PV valves on the control panel will begin the sequence. Cylinder W goes negative to release stones from hopper W onto the quarry belt. Following detection by W1 cylinder X goes negative to release stones from hopper X onto the quarry belt.
- Following detection by X1 cylinder X goes positive and following detection by X2 cylinder W goes positive to close each of their hoppers. After detection by W2 cylinder Y goes negative to release stones from hopper Y onto the quarry belt.
- Following detection by Y1 cylinder Y goes positive to close hopper Y. After detection by Y2 a time delay begins to enable cylinder Z to go slowly negative to release stones from the larger hopper Z.
- After detection by Z1 cylinder Z goes positive to close hopper Z.
- Emergency stops can be activated from either position to stop the air supply. [18]

(d) On the pro forma provided, (**answer numbers 4(d)(i) and (ii)**) and using the minimum number of components design and draw a system which will:

(i) Use the air bleed in **Fig. 4(d)(i)** to activate the stone riddle cylinder to reciprocate automatically with speed control. This will allow the quarry stones to be riddled and will prevent larger stones passing into hopper W. [5]



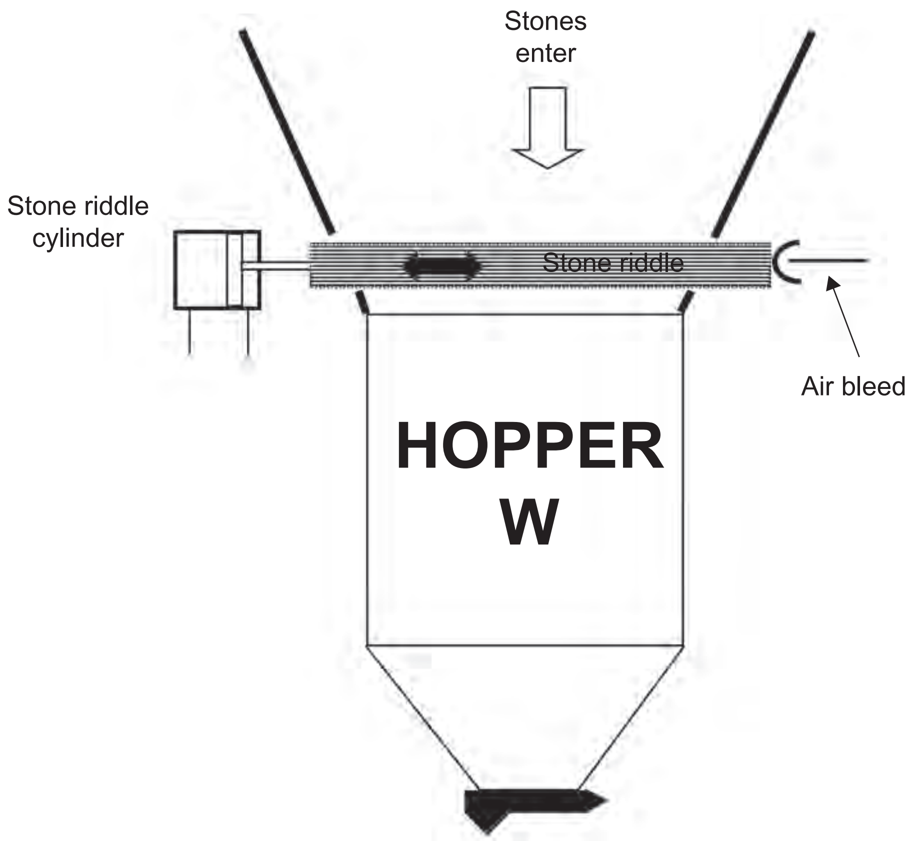


Fig. 4(d)(i)

(ii) Use a proximity sensor in **Fig. 4(d)(ii)** to detect when hopper Z is full of stones. Once detected, cylinder A will go positive, allowing the bell to be struck once via a suitable mechanism involving the pivot. Hopper Z will empty immediately and the return of the cylinder will happen after a short time delay using the exhaust air from cylinder A. [5]

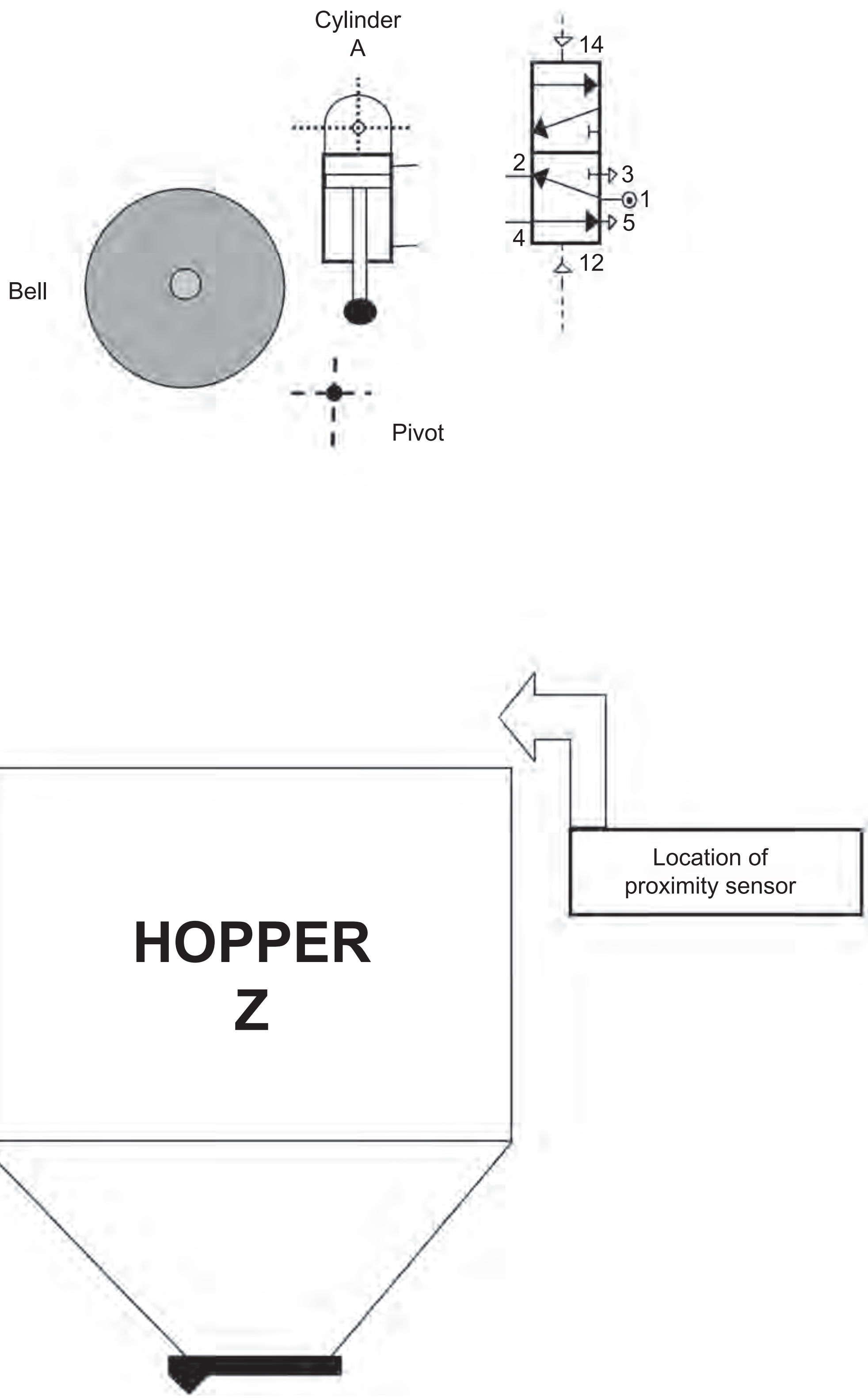


Fig. 4(d)(ii)

Answer **either** the **two** questions in Section C or the **two** questions in Section A or Section B.

Section C

Product Design

5 Trampolines, such as the one shown in **Fig. 5**, are designed and manufactured by companies in a wide range of sizes and shapes and are available with enclosures and accessories to suit different markets.

Specification Points	
Maximum weight on bed	150 kg
Assembly skills required	Intermediate
Time taken to assemble	Approximately 1 hour
Maximum deflection of surface for bouncing on with 150 kg	0.5 metres
Warranty	5 years against rust for frame – 1 year for bed, padding and enclosure

Fig. 5

During the design stage of the trampoline companies are encouraged to develop proposals which reflect the potential impact on the environment.

(a) Outline **one** example of an environmental issue which a company should consider when developing design proposals. [1]

(b) When conducting market research companies need to consider the use of probability and non-probability sampling in order to determine appropriate clients for the survey.

(i) Explain how probability sampling could be used in market research by companies designing and manufacturing trampolines. [2]

(ii) Explain how non-probability sampling could be used in market research by companies designing and manufacturing trampolines. [2]

(c) A consumer guide magazine is proposing to carry out tests on the trampoline in order to verify and check the validity of the specification.

Select any **two** of the specification points outlined in **Fig. 5** then devise and explain **one** appropriate test for each selected point that could be used to test the trampoline. [4]

(d) In order to improve sales and promote the product companies need to consider a promotional strategy.

Explain **three** distinctly different promotional methods which a company selling this product could consider in order to achieve their strategy. [6]

(e) Variations exist between various product life cycles.

Use **five** different examples of life cycles to illustrate the variations which exist between these life cycles. [5]

Quality of written communication [4]

(f) The design of products can individually or collectively incorporate moral or environmental factors.

(i) Select **one** suitable product and explain how it incorporates moral factors in its design. [2]

(ii) Select **two** different suitable products and explain how they incorporate environmental factors in their design. [4]

(g) (i) With reference to **Fig. 5(g)** below and using the blank A3 pro forma provided (**answer numbers 5(g)(i) and (ii)**), design graphical information which could be printed on the bouncing surface of the trampoline to convey to parents, guardians or the user the following information:

- No more than one person should be on the trampoline at any one time.
- The space below the trampoline at all times must be clear and not used for storage. [5]

Trampolines which are temporarily secured down using a peg through the bracket into the ground (**Fig. 5(g)**) are sometimes subject to uplifting during stormy conditions.

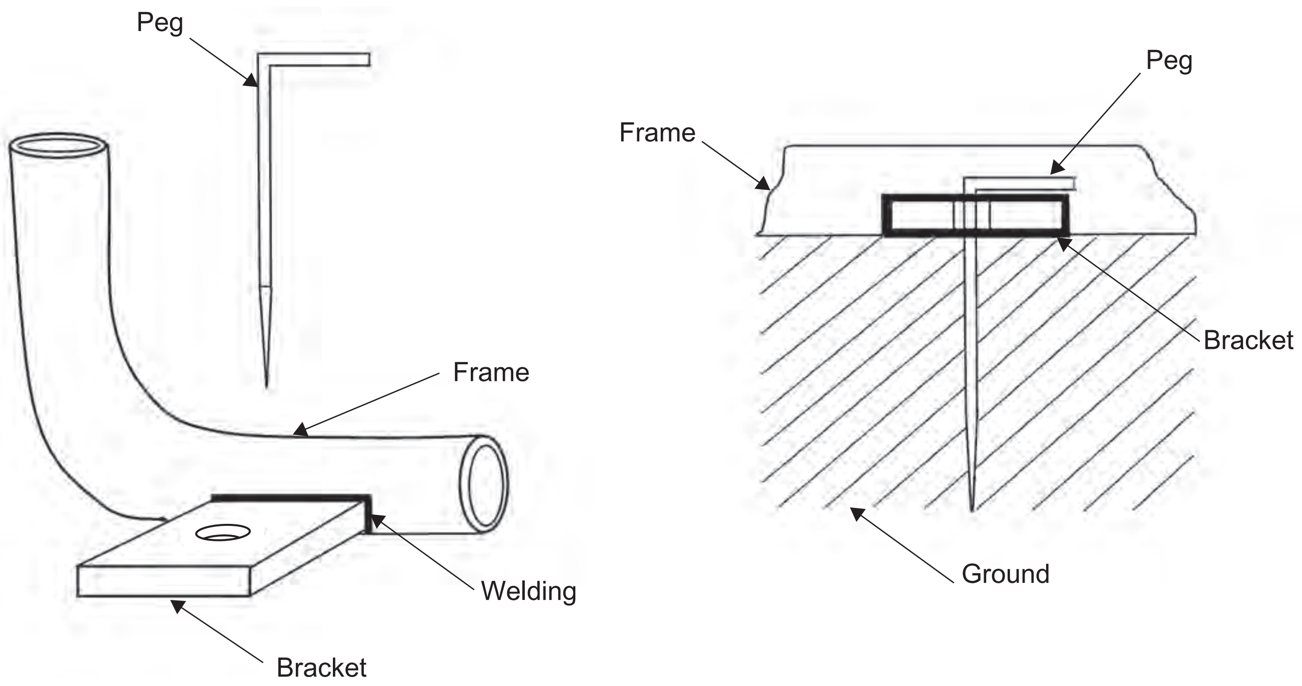


Fig. 5(g)

(ii) Using the blank A3 pro forma provided (**answer numbers 5(g)(i) and (ii)**) redesign the peg and bracket shown in **Fig. 5(g)** to ensure the trampoline is more securely fastened to the garden ground whilst ensuring the minimum use of materials. Provide a means of ensuring that the peg does not get lost when not in use. [5]

6 **Fig. 6** below shows a garden kneeler which has been designed and manufactured by a local company which specialises in outdoor garden equipment. The garden kneeler is designed to take the strain out of getting up and down to do garden tasks.

Fig. 6

Like many other products the kneeler has experienced the inception stage of the product life cycle.

(a) Explain what is meant by the inception stage of the product life cycle. [2]

(b) The company designing and manufacturing the garden kneeler has completed an environmental audit and a life-cycle assessment.

(i) Explain what is meant by an environmental audit. [2]

(ii) Explain what is meant by a life-cycle assessment. [2]

(c) When researching the market environment the company considered the impact of family roles and economic trends and how these might influence outdoor garden products.

Briefly explain the type of information that would be gained by researching each of the following and suggest how this might influence outdoor garden products:

- Family roles.
- Economic trends. [4]

(d) The company was given advice on market research which suggested they could make use of Hall tests, retail audits, omnibus surveys and postal questionnaires.

(i) Explain **two** main characteristics associated with each of the following:

- Hall tests.
- Retail audits.
- Omnibus surveys. [6]

(ii) Briefly outline **three** main advantages and **three** main disadvantages associated with the use of postal questionnaires as a means of collecting information. [6]

(e) When determining a suitable price for the garden kneeler the company needs to consider using the cost-plus pricing method, while being aware of the elasticity of demand for the product.

(i) Explain what is meant by the cost-plus pricing method. [2]

(ii) Explain why it is important to the company to consider the elasticity of demand for the product. [2]

(f) CAD, CAM and other ICT systems are widely used in the design and manufacture of many products including the garden kneeler shown in **Fig. 6**.

Explain the use of **two** other ICT systems which could be used in the design and manufacture of the garden kneeler shown in **Fig. 6** (no reference should be made to CAD or CAM systems in your answer). [4]

(g) **Fig. 6(g)** below shows side views of the garden kneeler. In addition, two commonly used garden tools are also shown which will need to be located on a rack which can be quickly attached to the tubular steel frame and positioned for easy access during gardening work.

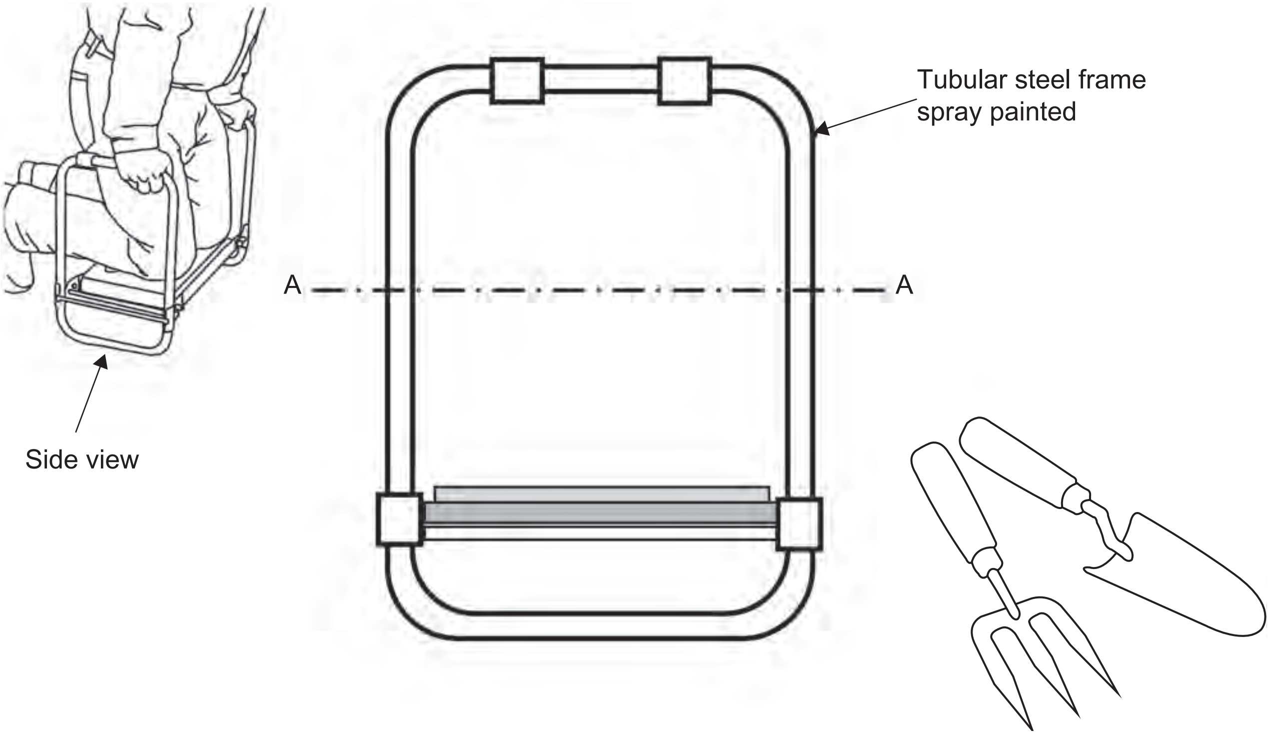


Fig. 6(g)

(i) With reference to **Fig. 6(g)** above and using the blank A3 pro forma provided (**answer numbers 6(g)(i) and (ii)**) produce annotated sketches of a suitable design that will enable the user to quickly adjust the height of the tubular steel frame (at the position shown in **Fig. 6(g)** (A–A)) in order to provide a more comfortable height. Show how your design prevents damage to the paintwork as the frame moves up or down. [4]

(ii) With reference to **Fig. 6(g)** above and using the blank A3 pro forma provided (**answer numbers 6(g)(i) and (ii)**), produce annotated sketches of a suitable storage rack containing the two garden tools secured to the tubular steel frame of the garden kneeler. Show how your design fulfils the following requirements:

- Allows the user to quickly attach/remove the storage rack containing the two garden tools to and from the side of the garden kneeler. [2]
- Displays the two garden tools to facilitate easy access for use. [2]
- Uses the minimum amount of material and requires the minimum number of manufacturing processes in order to provide a commercially viable product. [2]

THIS IS THE END OF THE QUESTION PAPER

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Question No. 1(e)(ii)

ADVANCED LEVEL TECHNOLOGY AND DESIGN
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Pro forma answer page
(answer number 1(e)(ii))

Question No. 2(d)

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(answer number 2(d))

Question No. 3(d)(i)

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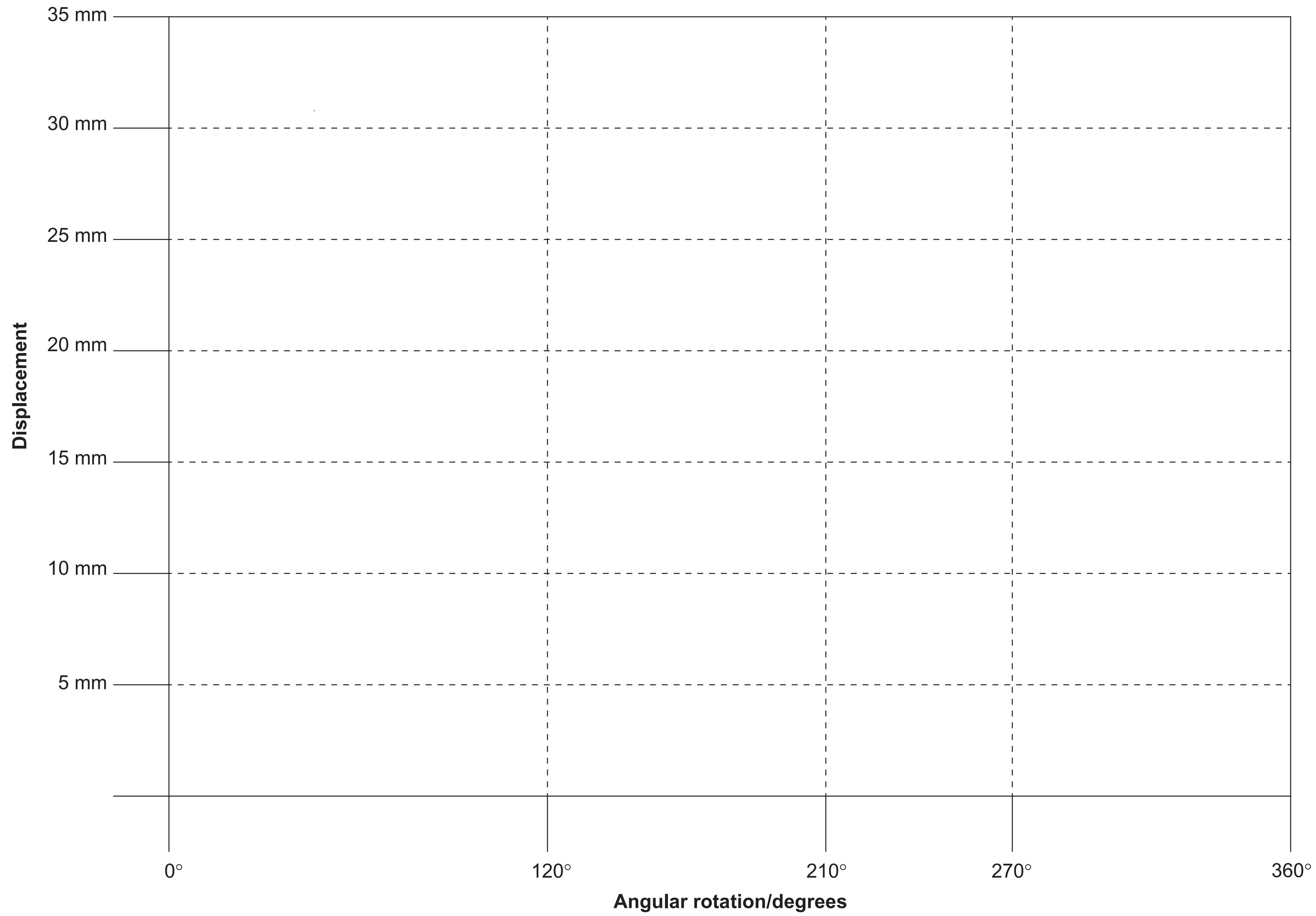

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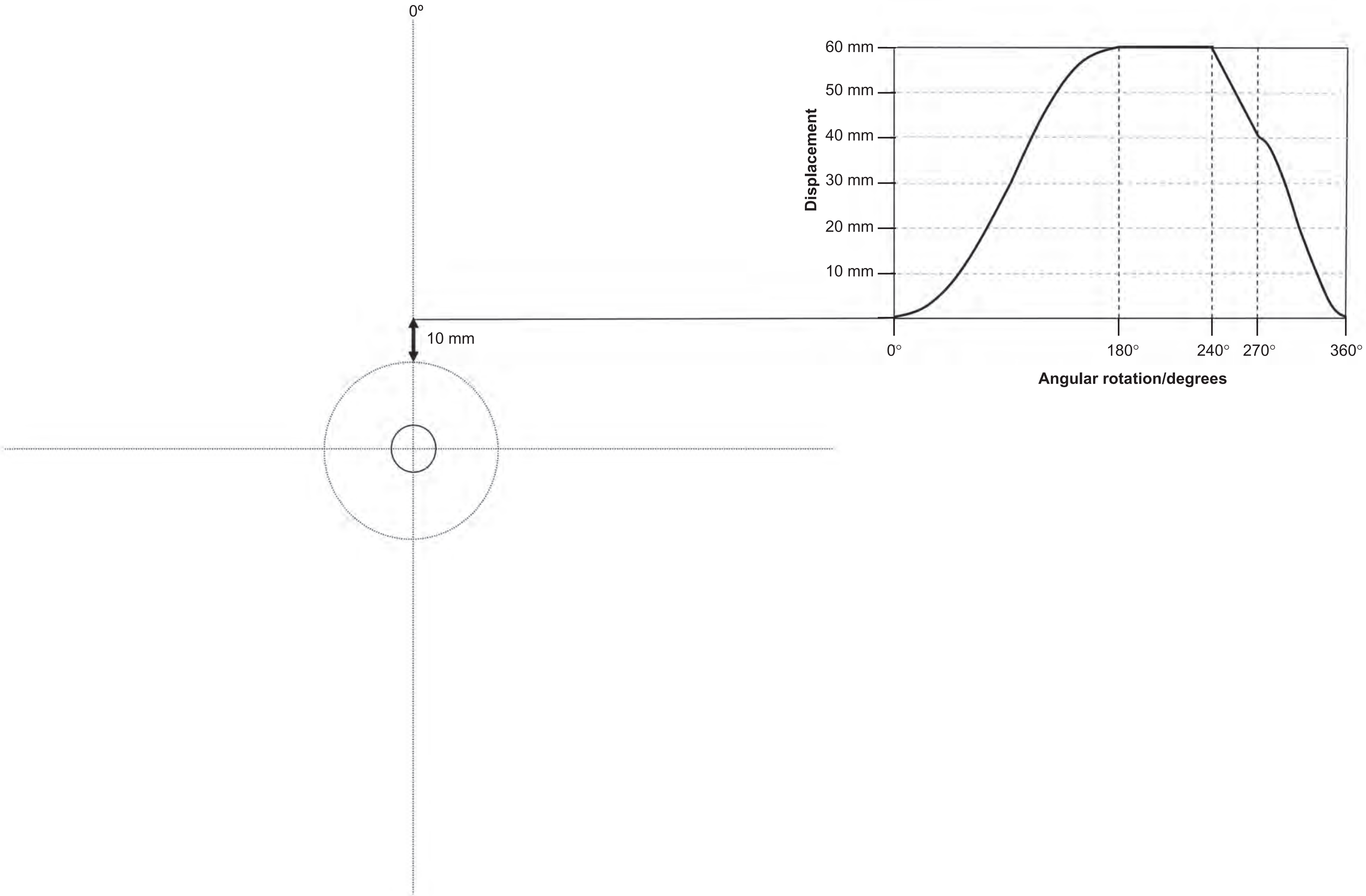

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Pro forma answer page
(answer number 3(e)(ii))

Question No. 4(c)

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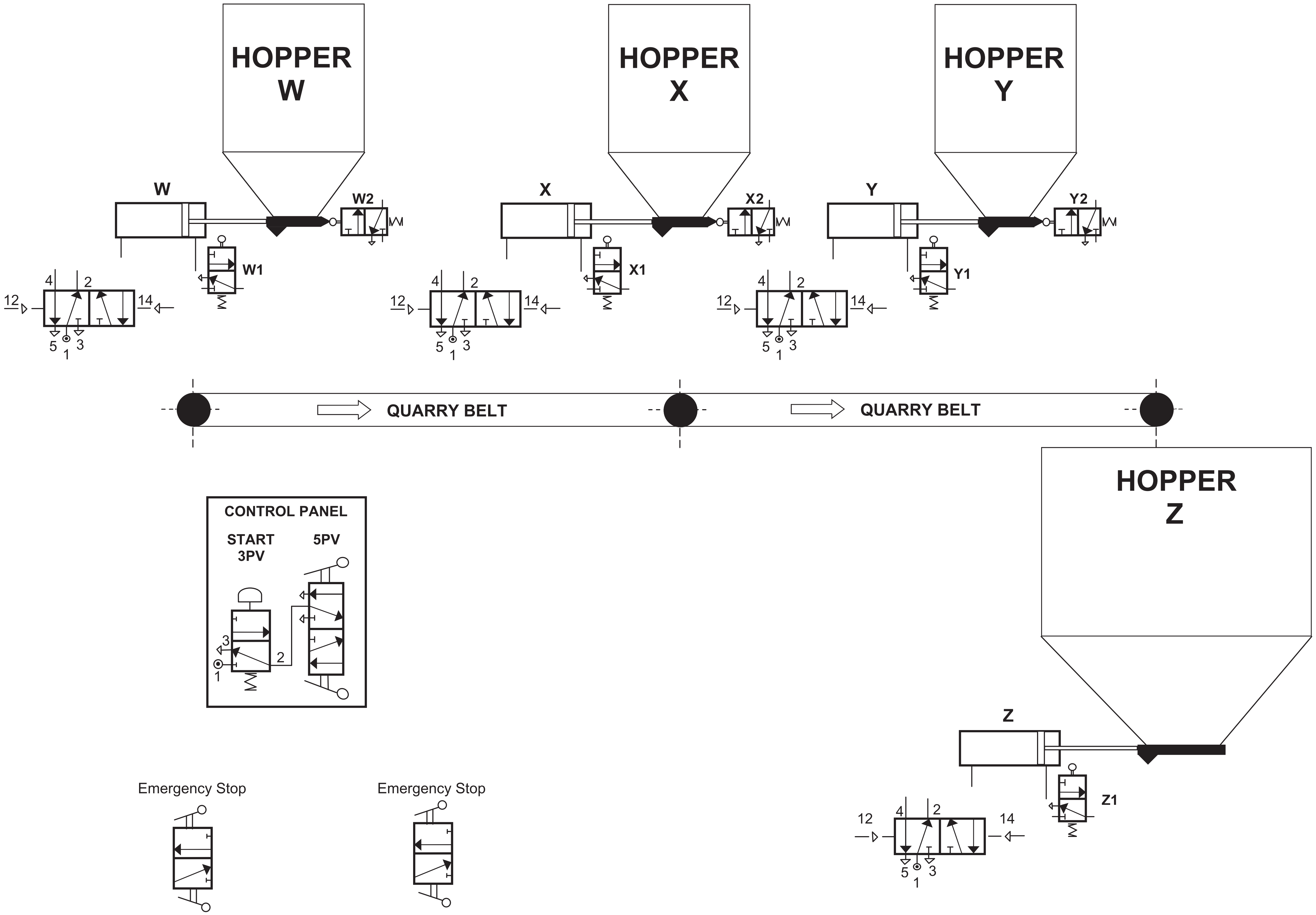

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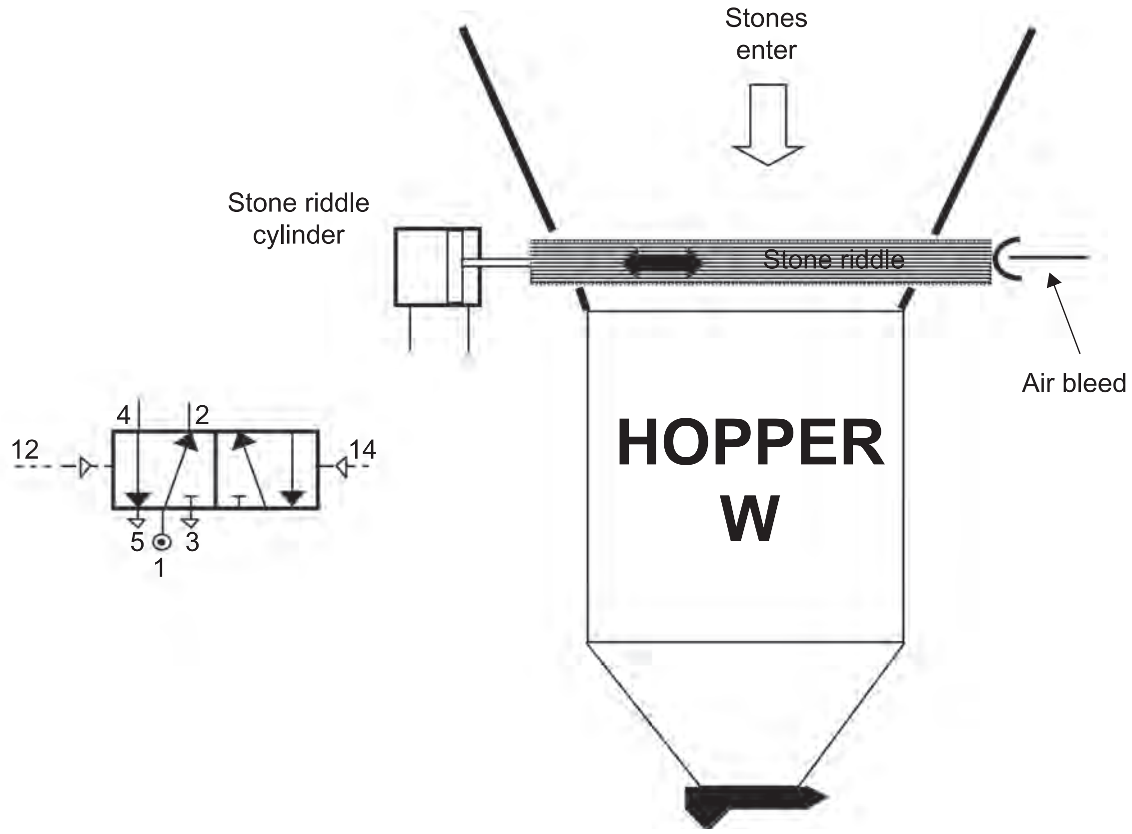

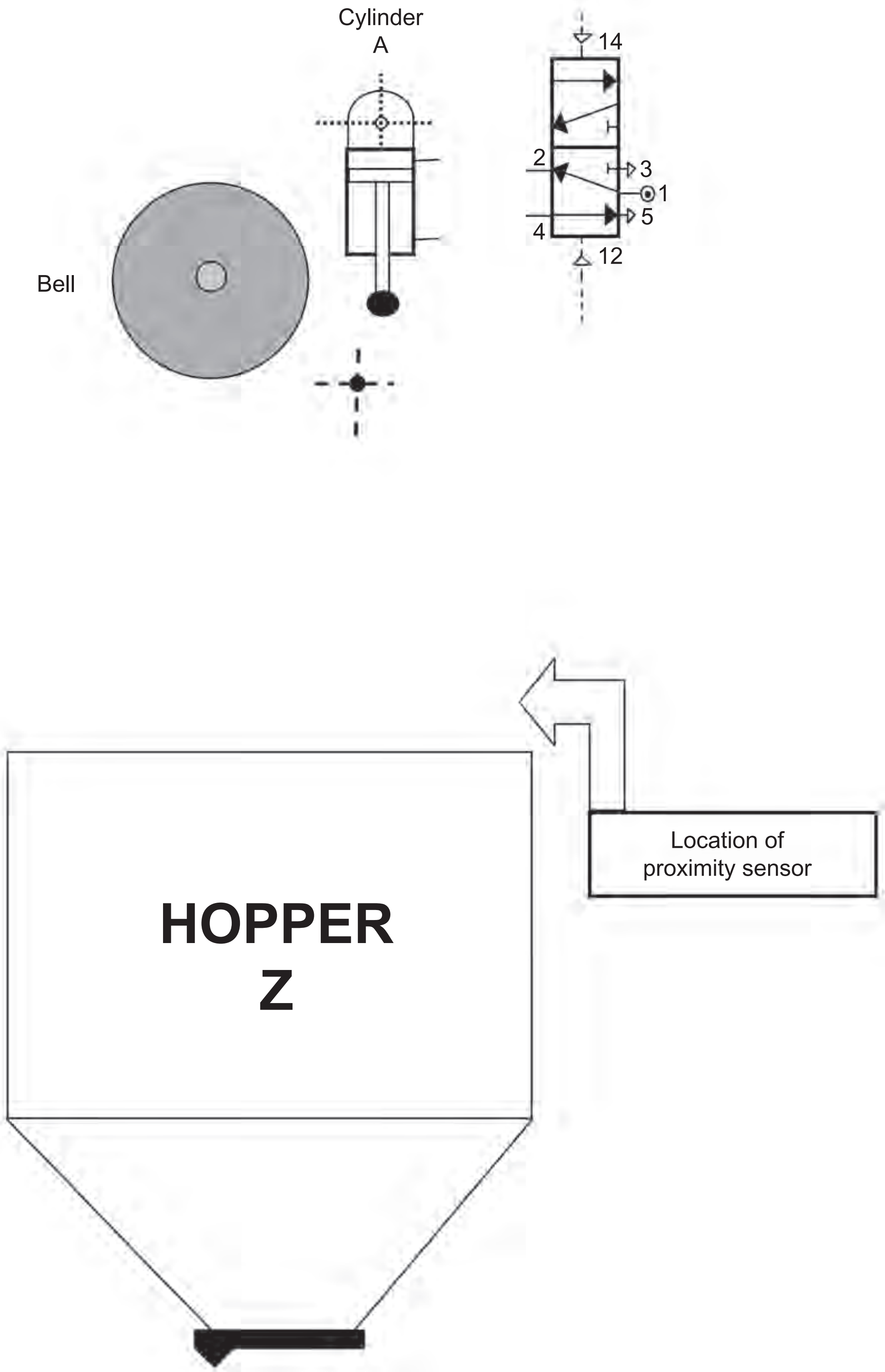

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Pro forma answer page (answer number 4(d)(ii))

Question No. 5(g)(i) and (ii)

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Pro forma answer page
(answer numbers 5(g)(i) and (ii))

Question No. 6(g)(i) and (ii)

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Pro forma answer page
(answer numbers 6(g)(i) and (ii))