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# Technology and Design

Assessment Unit A2 1

*assessing*

Systems and Control

and

Product Design



AV211

[AV211]

**MONDAY 23 MAY, MORNING**

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## 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 **two** questions from either Section A, Section B **or** Section C.

Answers to Questions **1(e)**, **2(e)**, **3(d)(i) and (ii)**, **3(e)(i) and (ii)**, **4(c)**, **4(d)(i) and (ii)**, **5(h)(i) and (ii)** and **6(h)** 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.

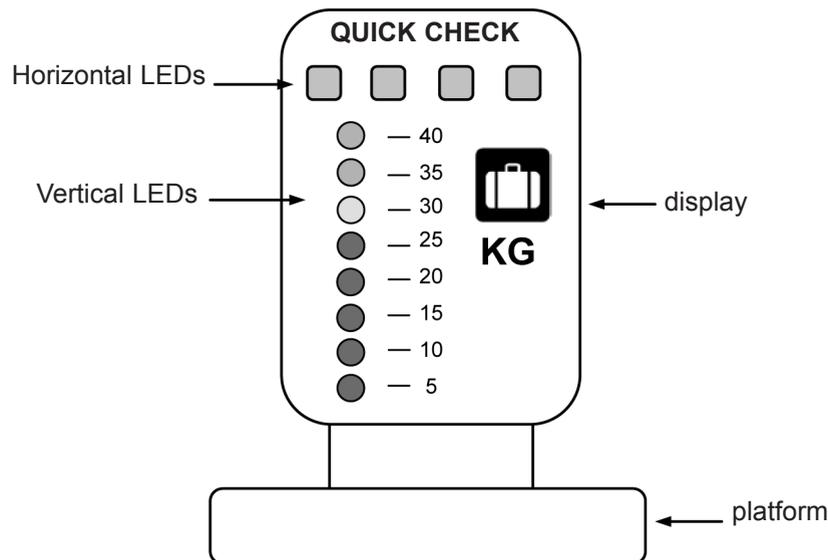
Marks for quality of written communication will be awarded for Questions **1(f)**, **3(c)** and **5(e)**. Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

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

## Section A

### Electronic/Microelectronic Systems

- 1 **Fig. 1** shows the display for a prototype system that has been devised to indicate baggage weight at an airport terminal. A row of horizontal LEDs will continuously flash in an eye catching sequence and the vertical LEDs will indicate weight to the nearest 5 kg when an item of baggage is placed on the platform. A strain gauge is to be used as the input sensor.



**Fig. 1**

- (a) (i) State the main physical property of a strain gauge that changes when the gauge is deformed. [1]
- (ii) Explain the distinction between the active and passive axis on a strain gauge. [2]
- (iii) State the effect of increased temperature on a strain gauge and briefly explain how this can cause errors when using the gauge. [2]

- (b) A strain gauge attached to the platform in **Fig. 1** is connected as part of a Wheatstone bridge as shown in **Fig. 2** where  $R_G$  represents the resistance of the strain gauge and  $R_1$ ,  $R_2$  and  $R_3$  each have a resistance of  $120.0\Omega$ .

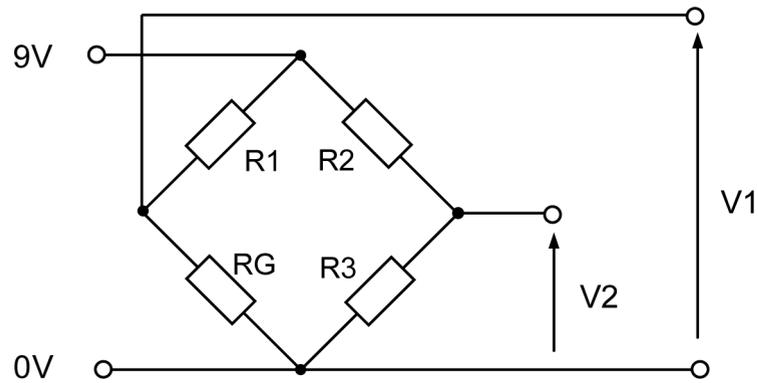
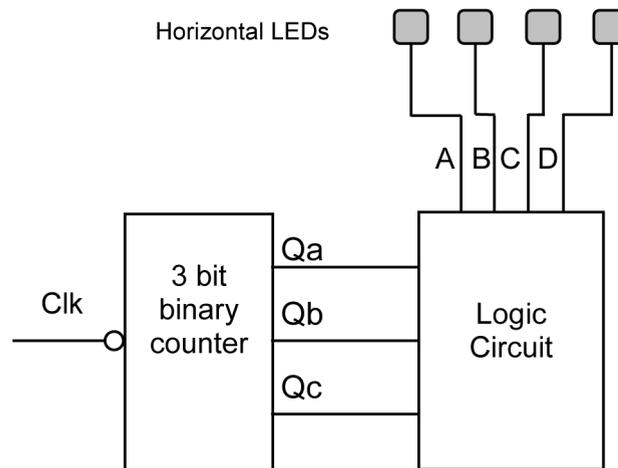


Fig. 2

- (i) Determine the voltage at  $V_2$  in **Fig. 2**. [1]
- (ii) During testing it was found that the resistance value of  $R_G$  in **Fig. 2** was  $120.3\Omega$  when the platform in **Fig. 1** was holding the maximum load of 40 kg. Calculate  $V_1$  when the platform is holding the maximum load. [2]
- (c) The voltages  $V_1$  and  $V_2$  from the Wheatstone bridge circuit shown in **Fig. 2** are to be connected to an op amp based circuit in differential mode where  $V_o = (R_f/R_i)(V_1 - V_2)$ .
- (i) Calculate the gain of the differential amplifier if the maximum output voltage required is to be 3V when the platform is holding the maximum load. [2]
- (ii) Draw the differential amplifier choosing suitable values for the resistors  $R_f$  and  $R_i$  to achieve the gain calculated in (c)(i). Also add labels to show  $V_1$ ,  $V_2$  and  $V_o$ . [4]

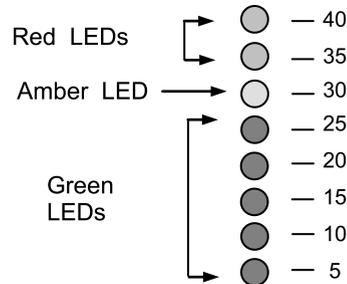
- (d) The display for the baggage weighing system has a row of four coloured LEDs, A, B, C and D which are arranged as shown in **Fig. 3**. The LEDs flash with a repeating sequence controlled by the outputs from a logic circuit which in turn is controlled by a binary counter. As the outputs from the counter  $Q_a$ ,  $Q_b$  and  $Q_c$  are incremented from 000 to 111 the LEDs are to be switched on in the following sequence, A only, B only, C only, D only, C only, B only, A only, all off.



**Fig. 3**

- (i) Name **one** method used to simplify truth tables. [1]
- (ii) Draw a truth table for the counter outputs  $Q_a$ ,  $Q_b$  and  $Q_c$  as the counter is incremented from 000 to 111 (assuming that  $Q_a$  is the LSB). The truth table should also include columns for the outputs A, B, C and D showing when the LEDs are on. Assume a '1' corresponds to an LED being on. [2]
- (iii) Write logic expressions for the outputs A, B, C and D minimising where possible. [4]

- (e) The display for the baggage weighing system has eight vertical LEDs as shown in **Fig. 4**. Each LED represents 5 kg in weight. The bottom five LEDs are green in colour, the sixth LED is amber while the seventh and eighth LEDs are red. The output from the differential amplifier in question **1(c)** is connected to the analogue input (i/p1) of a PIC. The voltage range of the analogue input ranges from 0V to 3V and the corresponding digital range is 0 to 255. The 8 outputs from the PIC (o/p0-o/p7) are connected to the eight LEDs and a buzzer.



**Fig. 4**

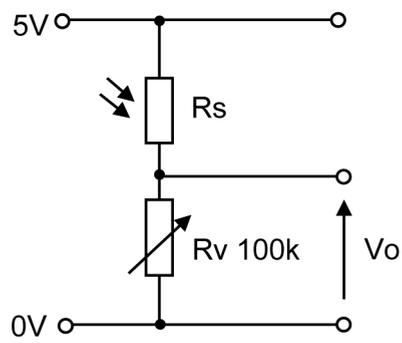
Using electronic circuit diagrams on the blank A3 pro forma provided (**answer number 1(e)**) design a PIC based circuit and associated flow chart program that will fulfil the following:

- Check the baggage weight on the platform at a rate of once every 1 second.
- Light each of the LEDs successively (keeping the previous LEDs on) for equally divided input voltage levels up to 3 volts corresponding to 5 kg up to 40 kg.
- If the weight reaches 40 kg the last red LED and a 12 volt buzzer should switch on and off once per second (on for  $\frac{1}{2}$  second and off for  $\frac{1}{2}$  second) until the baggage is removed. [10]

- (f) Designers of electronic systems can employ either PIC based or hard-wired circuits. Compare and contrast **three** main differences between these types of system. Supplement your answer with a specific example of where a hard-wired circuit could be chosen in preference to a PIC based circuit and justify why it would be chosen. [5]

Quality of written communication [4]

2 A voltage divider circuit is shown in **Fig. 5**.



**Fig. 5**

(a) (i)  $R_s$  in **Fig. 5** is an LDR. State how its resistance varies with light. [1]

(ii) Calculate the value for  $V_o$  in **Fig. 5** if  $R_v$  is set to its mid position and the resistance of  $R_s$  is  $60k\Omega$ . [2]

- (b) A student has designed a system for counting the number of pull-ups achieved by people in a gym. It consists of a housed light source (bulb) mounted on a bar and directed at the component  $R_s$  in the voltage divider from Fig. 5 which is also housed and mounted on the bar. Fig. 6 shows how the system is arranged. Each time the light beam from the bulb is broken a pull-up should be detected. The number of pull-ups will be counted using a BCD counter also shown in Fig. 6.

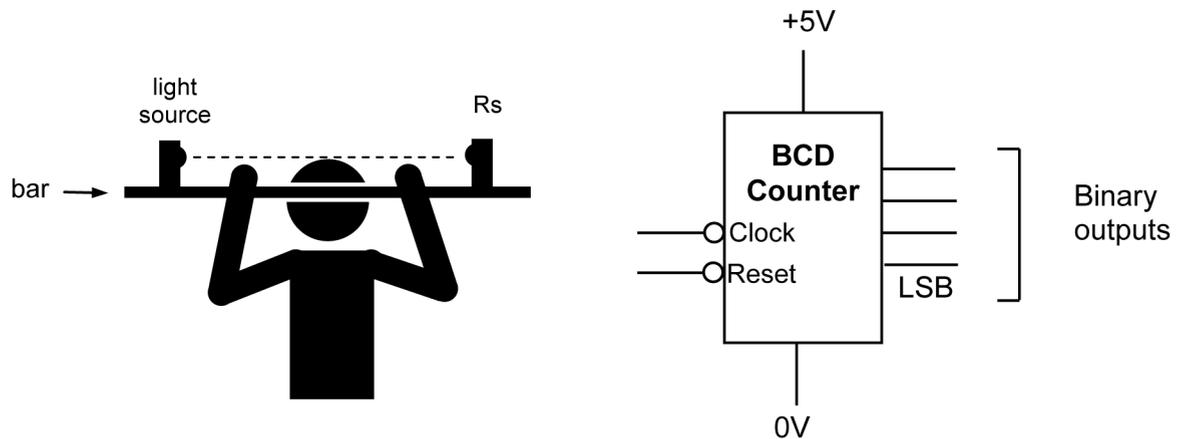


Fig. 6

- (i) The reset for the BCD counter shown in Fig. 6 is normally held at a high voltage and needs to be pulled momentarily low in order to reset the counter. Draw a circuit diagram to show how to achieve this, assuming the counter has a 5 volt power supply. [2]
- (ii) During initial testing it was found that the voltage divider output  $V_o$  shown in Fig. 5 did not provide a sufficient voltage range to operate the clock input on the BCD counter. It was suggested that a transistor could be utilised to provide an effective high to low voltage range using  $V_o$  from the voltage divider. Using an annotated diagram explain how a transistor based circuit could be used to provide a sufficient voltage range to operate a counter clock input. [4]

- (c) The number of pull-ups is to be displayed on a large seven segment display as shown in **Fig. 7**. A circuit diagram showing the arrangement of LEDs within each segment is also shown. The forward voltage of each LED is 1.8 volts and when a segment is illuminated the current in each LED is 15 mA.

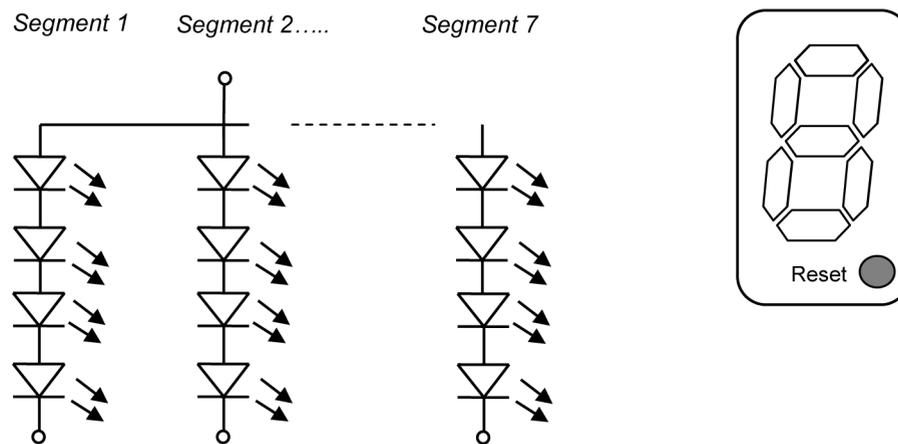
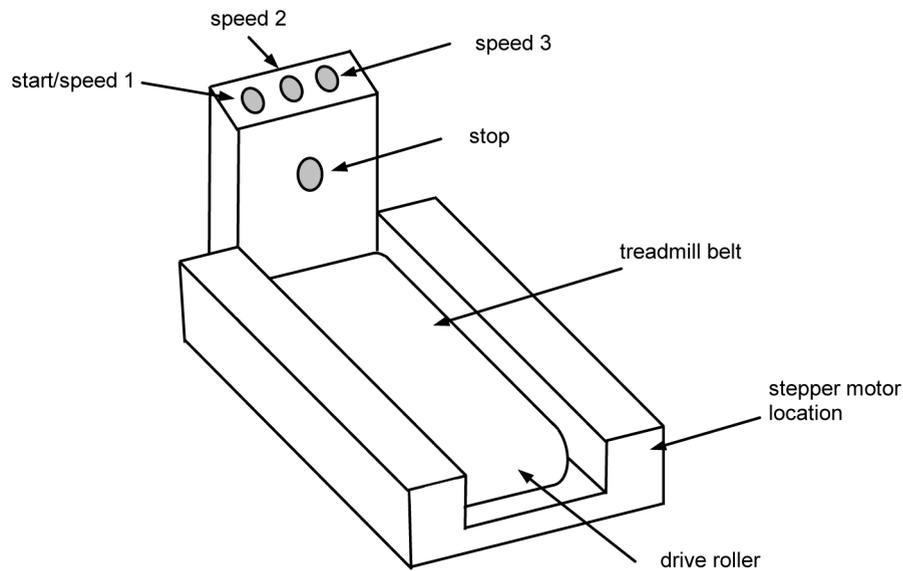


Fig. 7

- (i) Suggest **one** practical reason why four LEDs are arranged as shown in **Fig. 7** for each segment of the seven segment display. [1]
- (ii) State if the LED display shown in **Fig. 7** is connected in common anode or common cathode mode and briefly justify your answer. [2]
- (iii) Calculate the value for a protective resistor required for one segment of the display shown in **Fig. 7** if the power supply to the display is 9 volts. [2]
- (iv) Calculate the total power dissipated by the seven segment display shown in **Fig. 7** when the number zero is displayed (assume a current of 15 mA in each LED). [2]
- (v) Using a circuit diagram show how the binary outputs from the BCD counter shown in **Fig. 6** can be used to light the seven segment display shown in **Fig. 7** to enable up to nine pull-ups to be counted and displayed. Label any additional components required. [5]
- (vi) Draw a block diagram for the complete pull-up counter system labelling the input, control, driver and output sub systems. [2]
- (vii) State if the pull-up counter system is an open loop or closed loop system and justify your choice. [2]

- (d) **Fig. 8** shows a prototype for a basic treadmill for a gym. A heavy duty 24 volt stepper motor is to be used to drive a roller which will move the treadmill belt. The basic control panel has three push to make switches to select different speeds and a stop switch.



**Fig. 8**

- (i) State **two** advantages of using a stepper motor rather than a DC motor for the treadmill. [2]
- (ii) The stepper motor to be used in the prototype treadmill has a step angle of  $7.5^\circ$ . The treadmill will have three selectable speeds when moving 30 m/min, 60 m/min and 90 m/min. Determine the number of steps per second required to drive the stepper motor at 30 m/min if one rotation of the roller moves the treadmill belt by 250 mm. [3]
- (e) On the blank A3 pro forma provided (**answer number 2(e)**) design an annotated circuit to achieve the following:
- When the start/speed 1 switch is pressed the treadmill should run at 30 m/min and remain at this speed until the speed 2 switch is pressed.
  - When speed 2 switch is pressed the treadmill should run at 60 m/min until the speed 3 switch is pressed. (The operator of the treadmill should not be able to skip directly from speed 1 to speed 3.)
  - If either speed 2 or speed 3 switches are pressed without first pressing the start/speed 1 switch the treadmill must not run.
  - If the stop switch is pressed the treadmill will stop moving.  
(If your solution is PIC based it should be accompanied by a flow chart program.)
- [10]

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

## Section B

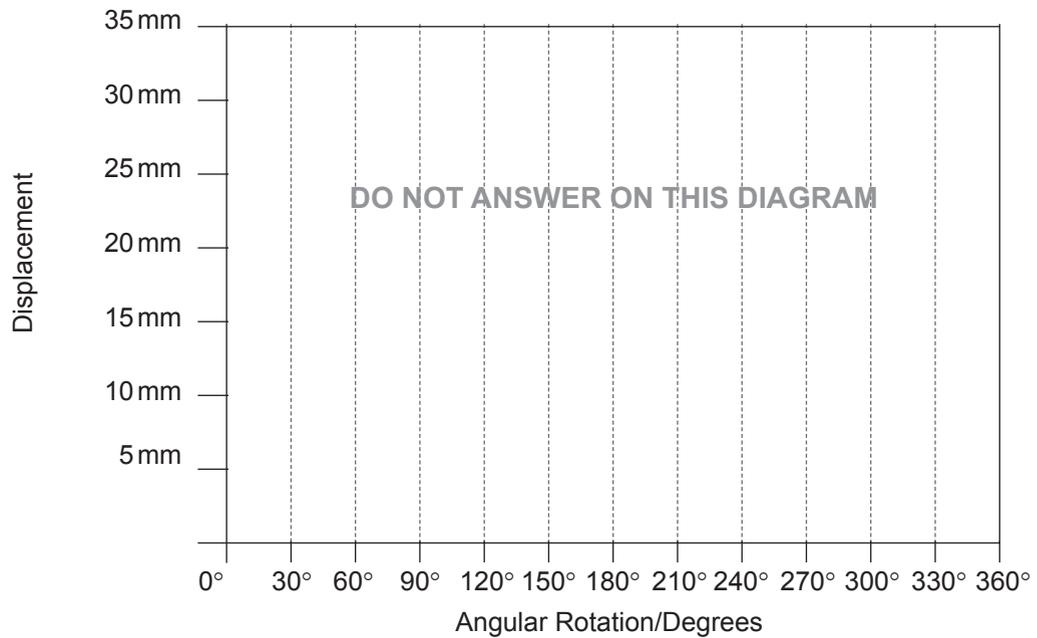
### Mechanical and Pneumatic Control Systems

- 3 Aeroplanes contain a range of mechanical systems that enable them to fully function.
- (a) (i) The gearbox on an aeroplane engine contains a range of gears. Briefly explain what is meant by the following terms:
- Simple gear train. [1]
  - Compound gear train. [1]
- (ii) One of the bolts that secures the lid onto the body of the gearbox is set to a torque of 120 Nm when the mechanic applies a force 600 mm from the centre turning point. Calculate the minimum force required to slacken the bolt. [2]
- (iii) A pump within the aeroplane has a piston which moves a total of 140 mm during one stroke at a speed of 1800 rpm. If the piston has a kinetic energy of 3.528 J, calculate its mass. [3]
- (b) Universal joints are used in the mechanical system of an aeroplane. With the use of an annotated sketch explain the main features of a universal joint. Also include a suitable method of fixing a universal joint to a drive shaft. [4]
- (c) Seals play a vital role in any lubricated system. Describe **two** characteristics of garter seals and **two** different characteristics of O-ring seals. Select the most appropriate seal for a hydraulic ram. [5]
- Quality of written communication [4]

(d) (i) Cams are used on the auxiliary service pump of the aeroplane. **Fig. 9** below shows a blank performance/displacement diagram which will be used for a cam profile. On the pro forma provided (**answer number 3(d)(i)**) construct a performance/displacement diagram which would accurately produce the following motion:

- 0–90° Simple Harmonic Motion rise 20 mm.
- 90–210° Uniform Velocity rise 15 mm.
- 210–300° Dwell.
- 300–360° Uniform Velocity fall 35 mm.

[5]

**Fig. 9**

(ii) Fig. 10 below shows another performance/displacement diagram.

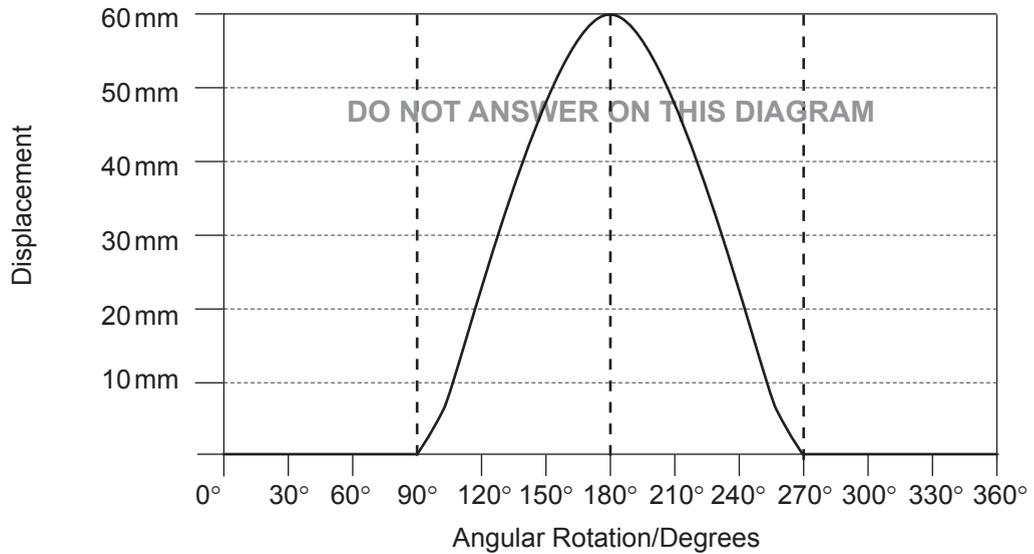


Fig. 10

On the A3 pro forma provided (**answer number 3(d)(ii)**), using an appropriate drawing technique, construct a cam profile which would accurately follow the performance/displacement diagram. The minimum cam diameter is 60 mm. The follower is a flat follower of 10 mm in length as indicated in the pro forma provided (**answer number 3(d)(ii)**) and the cam rotates in a clockwise direction. [5]

(e) (i) On the A3 pro forma provided (**answer number 3(e)(i)**) design, draw and annotate an appropriate mechanical system which would achieve the following requirements:

A method of raising and lowering the aeroplane wheels during take-off and landing using the hydraulic cylinder and a bell crank and any additional linkage. Your design must attach to the connector points, as shown. (You need only draw your design on one of the diagrams in either the raised or lowered position.) [5]

(ii) On the A3 pro forma provided (**answer number 3(e)(ii)**) design, draw and annotate an appropriate mechanical system which would achieve the following requirements:

On a smaller version of the prototype aeroplane the height is controlled by the elevator and control handle. To raise the aeroplane the elevator is moved to Position C when the control handle is moved forward to Position A. To lower the aeroplane the elevator is moved to Position D when the control handle is moved backwards to Position B. A small movement of the control handle produces a greater movement of the elevator.

Design a suitable mechanism to link the connector point on the control handle to the connector point on the elevator to achieve the desired movements outlined above. [5]

- 4 (a) (i) Safety is a key concern in the operation of pneumatics. Explain **two** main safety risks associated with pneumatics. [2]
- (ii) Outline the principle of operation of a vacuum pump and state a specific application for its use. [3]
- (b) (i) The work done by the single acting cylinder shown in **Fig. 11** is 1130.4 J during the outstroke. The cylinder has a stroke length of 100 mm and is supplied with an air pressure of 1 N/mm<sup>2</sup>. Calculate the diameter of the piston. Assume  $\pi = 3.14$ . [3]

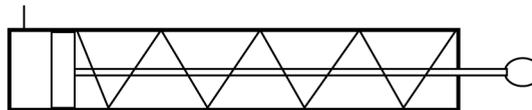


Fig. 11

- (ii) For a double acting cylinder calculate the difference between the positive and negative air consumption for an 80 mm diameter cylinder with a 300 mm stroke. The cylinder also has a piston rod diameter of 25 mm and working air pressure of 5 bar.

Assume atmospheric pressure = 1 bar.

Assume  $\pi = 3.14$ .

[5]

(c) The A3 pro forma (**answer number 4(c)**) shows a pneumatic system used for the production of aircraft seats. The production line follows these stages:

- Aluminium section enters the rollers from the manufacturing line. The sequence begins by operating the START 3PV.
- Cylinder A goes positive slowly to punch a slot in the aluminium. When Cylinder A is in the positive position it is detected by a micro switch.
- Following a time delay Cylinder B goes positive which enables a section of the aluminium to be milled.
- When Cylinder B is in the positive position it is detected by the roller trip 3/2 valve which is used to send Cylinder C positive which in turn bends a section of the aluminium.
- When Cylinder C is in the positive position it is detected by an air bleed which is used to send Cylinder C negative.
- When Cylinder C is in the negative position it is detected by the roller trip 3/2 valve which is used to send Cylinder B negative.
- When Cylinder B is in the negative position it is detected by the roller trip 3/2 valve which is used to send Cylinder D (guillotine) positive.
- When Cylinder D is in the positive position it is detected by an air bleed which is used to send Cylinder D (guillotine) negative.
- When Cylinder D is in the negative position it is detected by the micro switch which is used to send Cylinder A negative.
- When Cylinder A is in the negative position it is detected by the roller trip 3/2 valve which will reset any group valves used.
- Emergency stops can be activated from either position to stop the air supply.

On the pro forma provided (**answer number 4(c)**) draw a suitable pneumatic circuit with any additional components to achieve the stages outlined above. [17]

(d) On the A3 pro forma provided (**answer number 4(d)(i) and (ii)**) design and draw a system which will:

(i) Test the durability of the hinge on the aircraft seat storage tray using the double acting cylinder while counting the number of strokes as explained in the pro forma. The counter is incremented each time it receives a pulse of air. To aid testing a non-contact method must be employed to send the cylinder positive or negative and a means of starting and stopping the sequence should be included. [5]

(ii) Open and close the aircraft door using the piston rod connector on the double acting cylinder and the connectors using an appropriate mechanism.

The outcome must also enable the pilot to isolate the air supply during transit to prevent the cylinder accidentally releasing. The door can only be closed using micro switches A AND B and opened using micro switches C OR D. [5]

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

### Section C

#### Product Design

- 5 The cool box like the one shown in **Fig. 12** below is designed and manufactured by companies in a range of sizes and colours.



Fig. 12

- (a) Getting a product to the right place at the right time is an important consideration for any company.

Briefly explain why it is so important for a company producing cool boxes to get their product to the right place at the right time. [1]

- (b) Telephone interviews are a useful tool when conducting market research.

(i) Outline **two** main advantages associated with the use of telephone interviews as a means of assisting market research. [2]

(ii) Outline **two** main disadvantages associated with the use of telephone interviews as a means of assisting market research. [2]

- (c) For a company producing cool boxes researching demographic trends and life style changes can provide valuable information which can help shape future decisions.

(i) Briefly explain the type of information gained by researching demographic trends and how this might influence future decisions for a company. [2]

(ii) Briefly explain the type of information gained by researching life style changes and how this might influence future decisions for a company. [2]

(d) Fashion innovators and late adopters are two types of consumers who emerge at each stage of the product life cycle.

(i) Outline **two** main characteristics associated with fashion innovators. [2]

(ii) Outline **two** main characteristics associated with late adopters. [2]

(e) As designers and manufacturers strive to reduce the environmental impact of products the influence of the 6R's comes more into focus.

Select any **five** of the 6R's and explain with reference to practical examples (one example for each R selected) how they have been incorporated into your chosen examples. [5]

Quality of written communication [4]

(f) In addition to the 6R's designers and manufacturers need to consider the environmental impact that a product has during its life cycle. The life cycle stages involve the extraction of materials needed for the product, the processing of these materials, the manufacture and distribution of the product, the use of the product and the end of life considerations.

With reference to a product of your choice discuss the environmental impact the product may have for any **two** of the above stages of the product life cycle. [4]

(g) Fad and basic products have very different life cycles.

(i) Outline **two** main characteristics associated with the life cycle of a fad product. [2]

(ii) Outline **two** main reasons why basic products have a long product life cycle. [2]

(h) (i) With reference to **Figs. 13, 14 and 15** and using the blank A3 pro forma provided (**answer number 5(h)(i) and (ii)**) produce **one** suitable solution for the following:

Annotated sketches of a low cost design which will allow the user to quickly prop up the lid of the cool box (**Fig. 14**) allowing the inside to be ventilated which will help prevent mould. Show how your design is attached to the inside of the lid (**Fig. 15**). [4]



Fig. 13



Fig. 14



Fig. 15

(ii) Using the template on the A3 pro forma provided (**answer number 5(h)(i) and (ii)**) design graphical information which could be printed on an instruction leaflet to convey to the customer the following:

- The cool box is unsuitable for any member of the family to sit on.
- The top of the cool box containing the electrical components should not be covered when connected to the 12 volt socket in a car.
- Any drinks or liquids should not be set on the top of the cool box which contains the electrical components for the product.

[6]

6 Fig. 16 shows an extendable aluminium ladder aimed at the do it yourself (DIY) market.

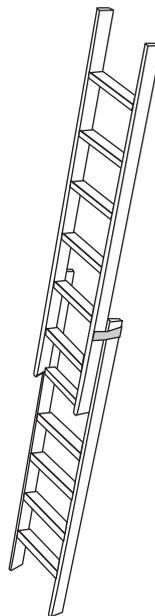


Fig. 16

(a) Briefly explain what is meant by an incremental product.

[1]

- (b) The company manufacturing the ladders is considering the use of wave and solar as alternative energy sources to power the company in order to drive down long term energy costs and utilise more sustainable sources.
- (i) Explain the principle of wave energy as a renewable source. [3]
- (ii) Explain the principle of solar energy as a renewable source. [3]
- (c) To gain a better understanding of the market place the marketing information system (MIS) conducts a number of research tasks. With reference to the ladder outline **two** types of information that might arise from each of the following tasks:
- Market analysis.
  - Price research. [4]
- (d) Computer aided design (CAD) and Computer aided manufacturing (CAM) and other ICT systems are employed in the design and manufacture of the ladder shown in **Fig. 16**.
- (i) Outline **three** different specific ways in which CAD may have been employed in the design of the ladder shown in **Fig. 16**. [3]
- (ii) Outline **two** different ways in which other ICT systems may have been employed in the design and manufacture of the ladder shown in **Fig. 16**. [2]
- (e) To determine the views of the consumer the company used both fixed consumer panels and product clinics. Explain **two** main aspects associated with each of the following:
- Fixed consumer panels.
  - Product clinics. [4]
- (f) The Memphis movement had a considerable impact on product design.
- Explain **two** main characteristics associated with the Memphis movement. [4]
- (g) The use of measuring devices, jigs and templates are an important element of Quality Control (QC).
- (i) With reference to a product of your choice explain how specific measuring devices are employed to assist QC. [2]
- (ii) With reference to a product of your choice explain how specific jigs are employed to assist QC. [2]
- (iii) With reference to a product of your choice explain how specific templates are employed to assist QC. [2]

(h) Fig. 17 below shows drawings of a double extendable aluminium ladder.

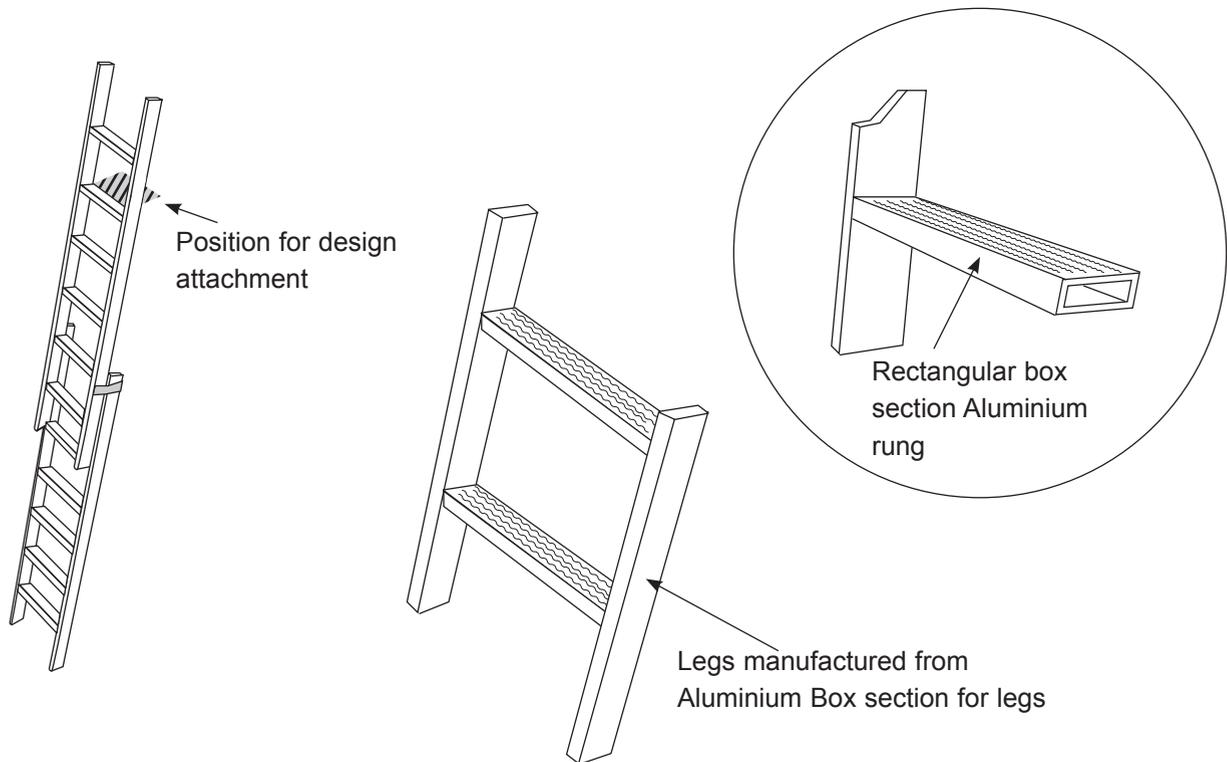


Fig. 17

On the blank A3 pro forma provided (**answer number 6(h)**) produce **one** suitable solution for the following:

- Detailed annotated sketches of a design attached to the ladder which would enable the user to quickly extend the length of one of the legs in order that both feet of the ladder are safely in contact with a firm surface so that it may be used on steps or sloping terrain. [5]
- Detailed annotated sketches of a design which can hold a small number of basic tools and can be quickly clipped securely onto the ladder in the position shown in Fig. 17. [5]

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**THIS IS THE END OF THE QUESTION PAPER**

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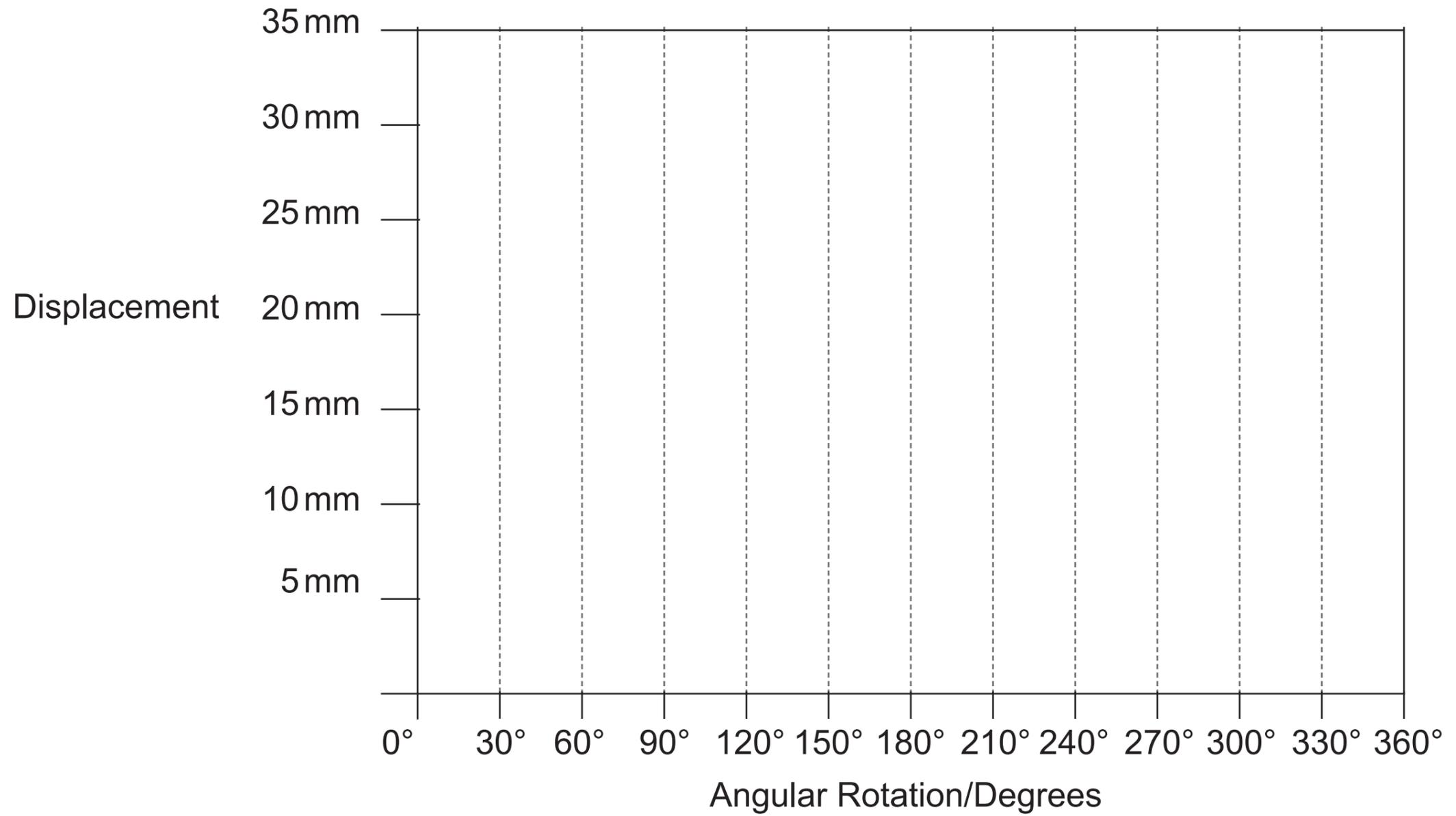
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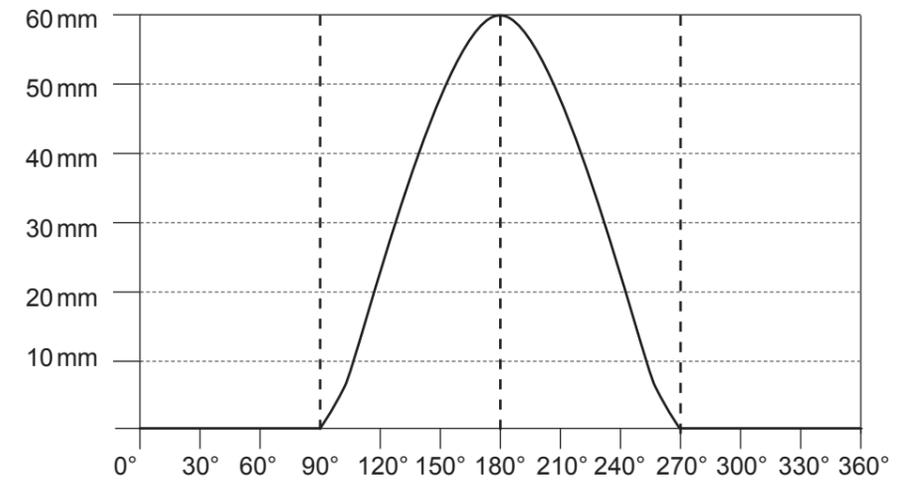
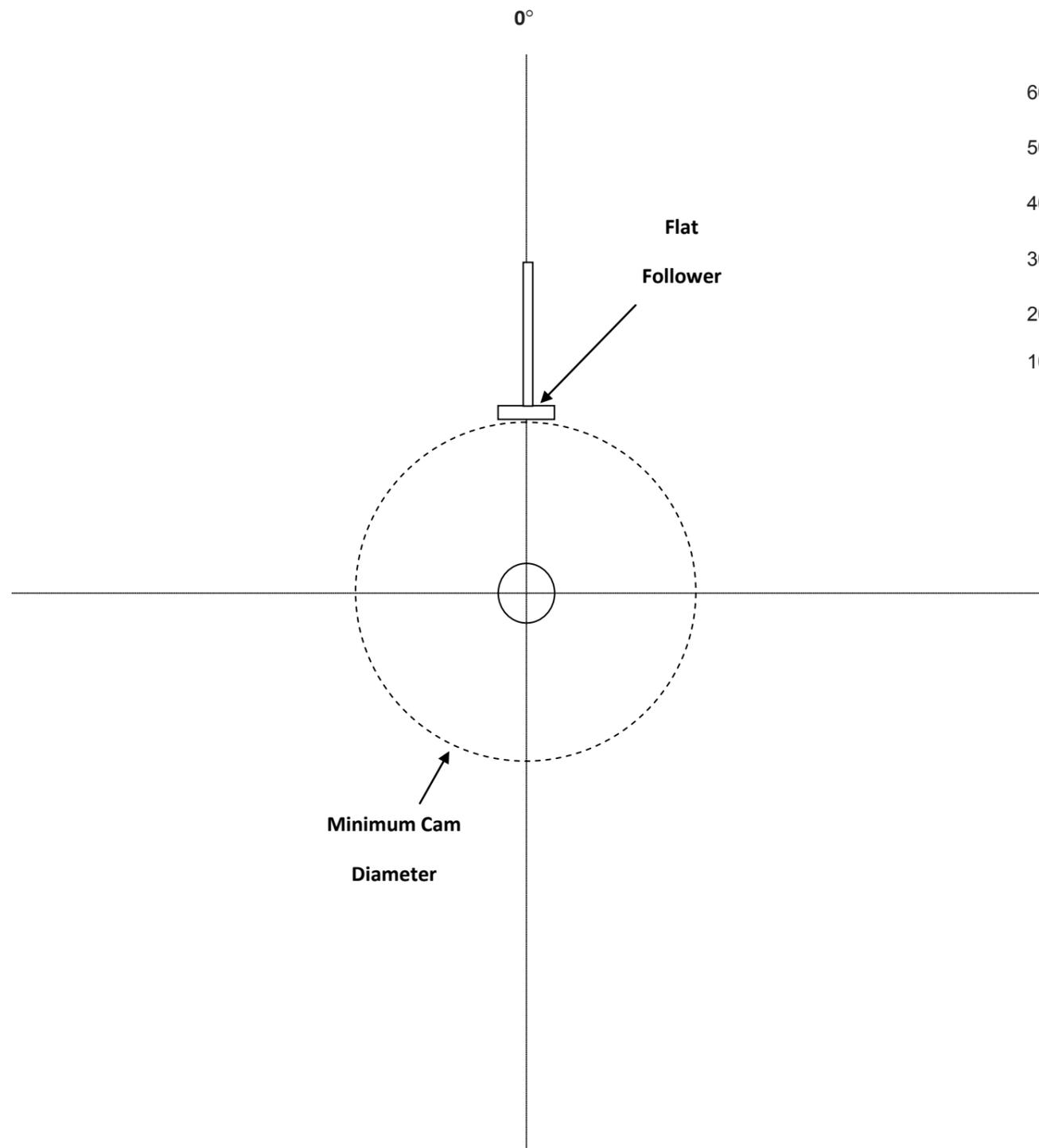


**Fig. 9**

**Pro forma answer page  
(answer number 3(d)(i))**

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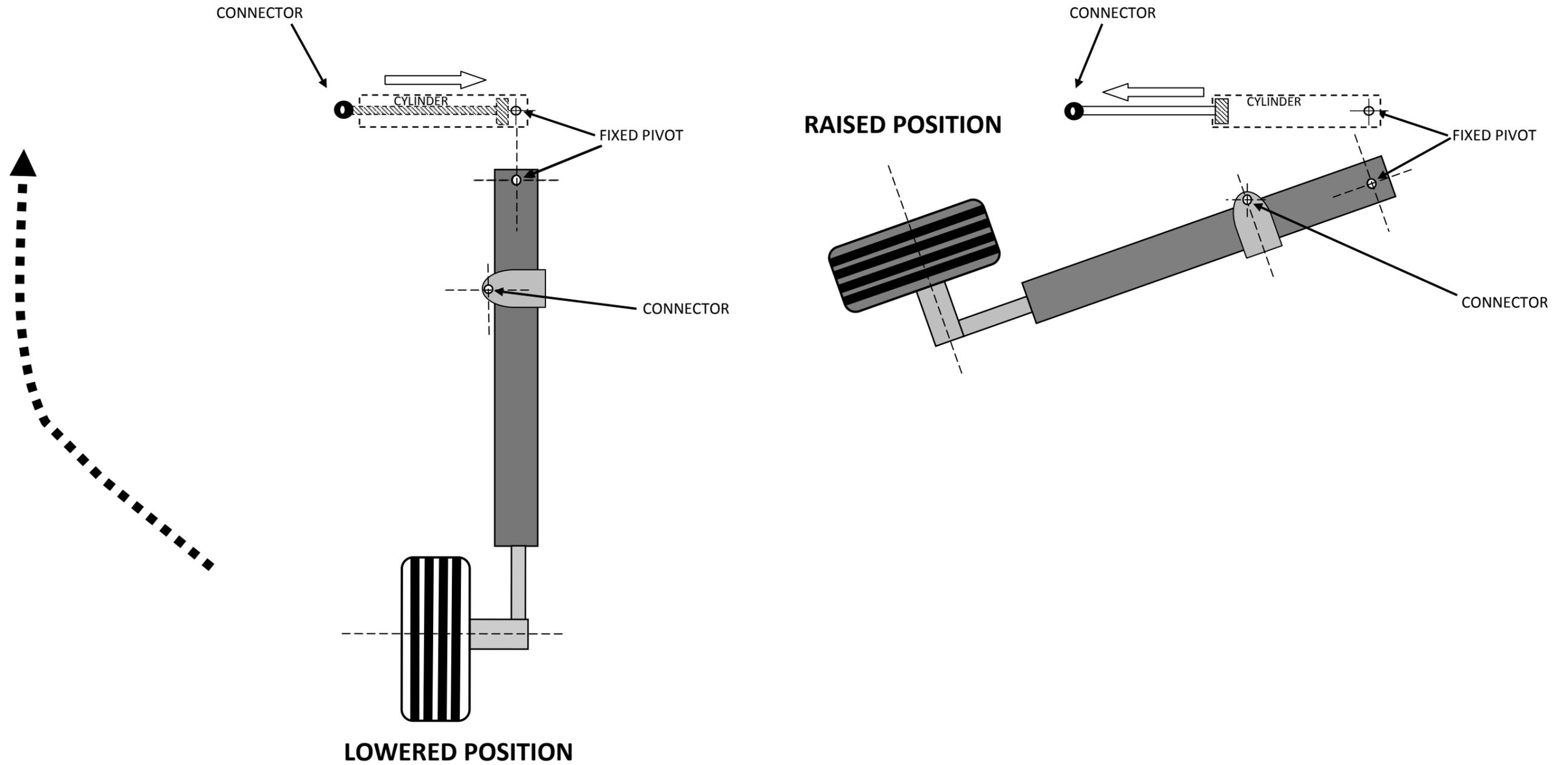
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Pro forma answer page  
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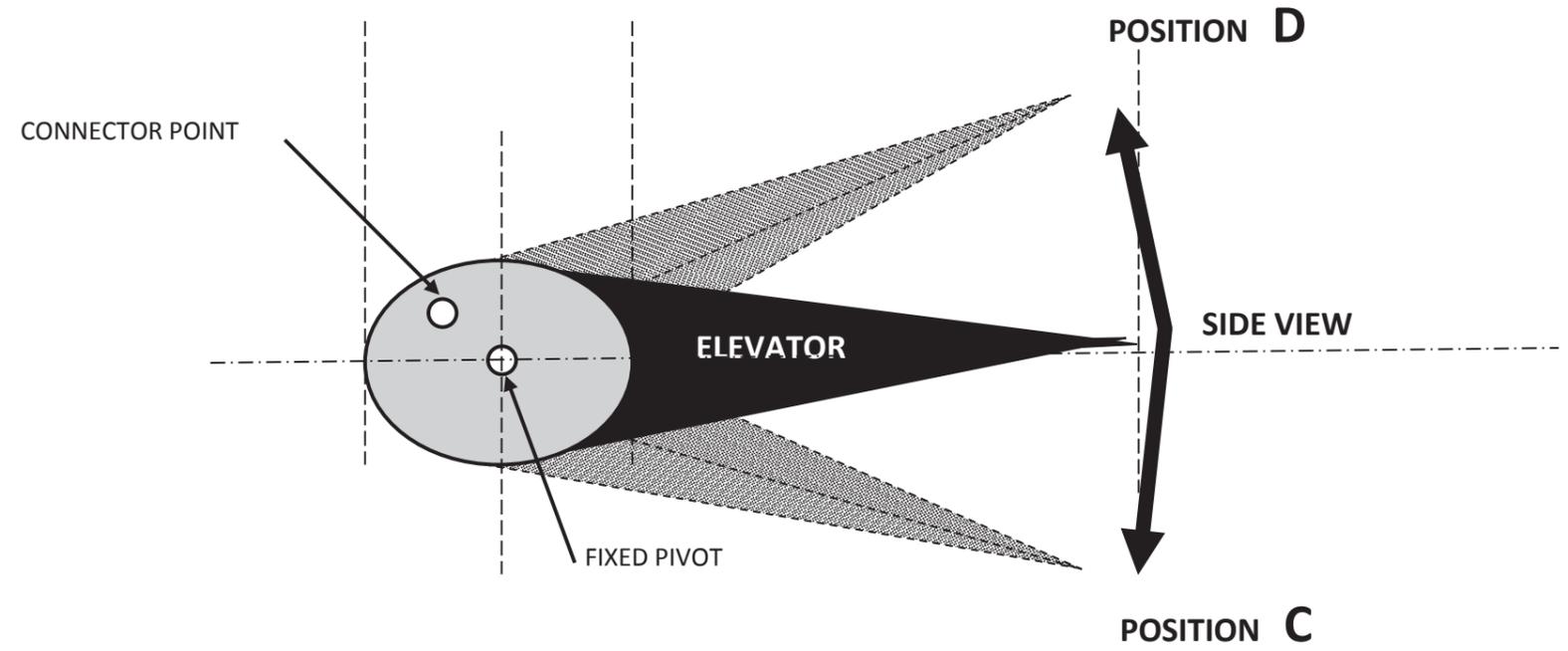
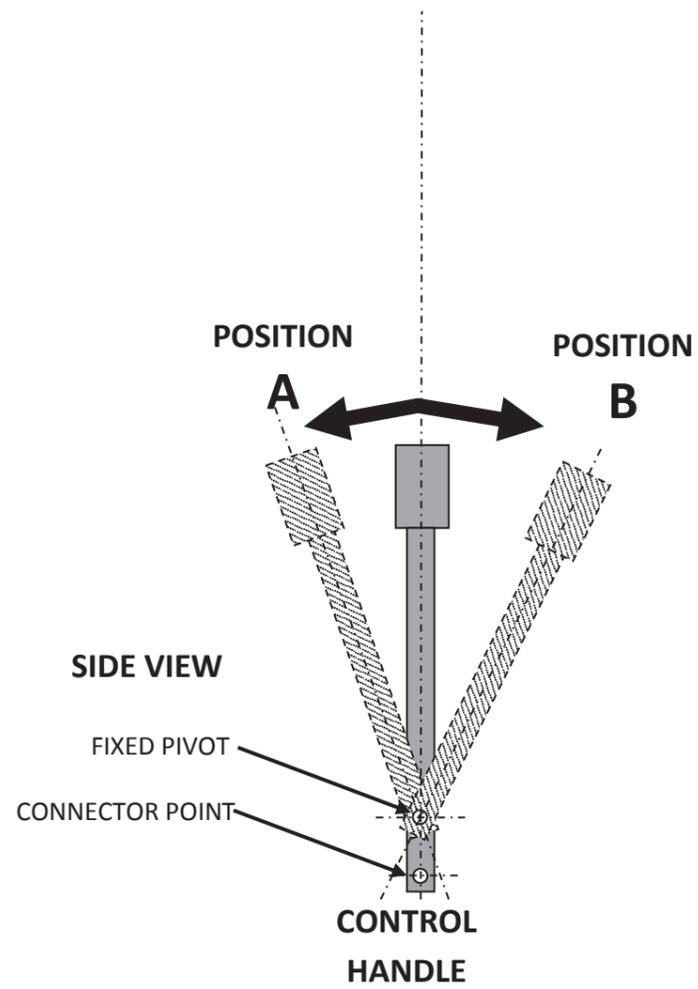
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Pro forma answer page  
(answer number 3(e)(i))

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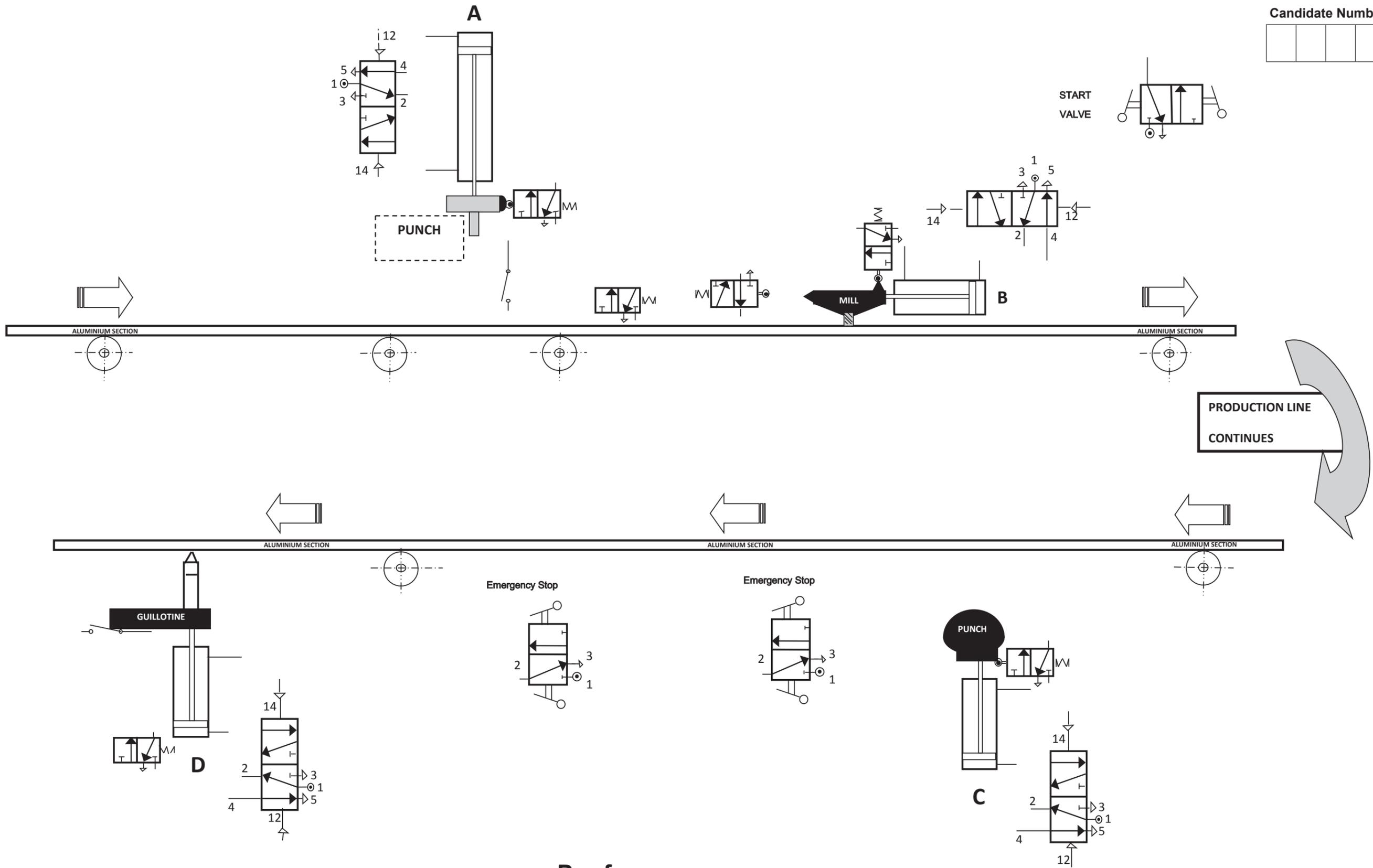
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Pro forma answer page  
(answer number 3(e)(ii))

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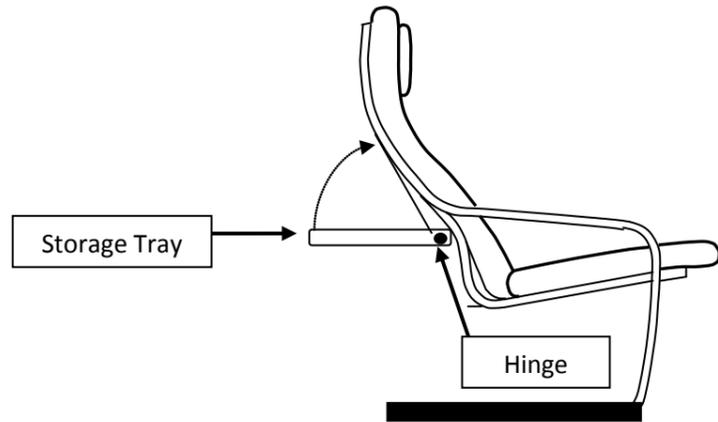
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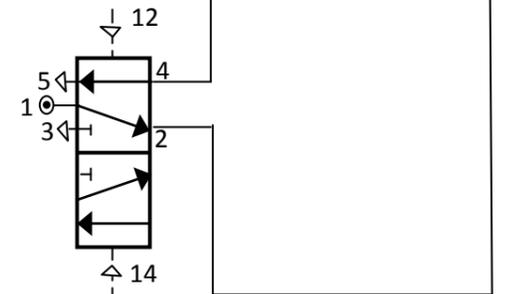
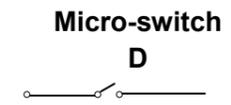
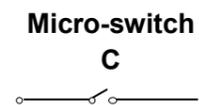
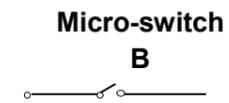
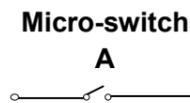
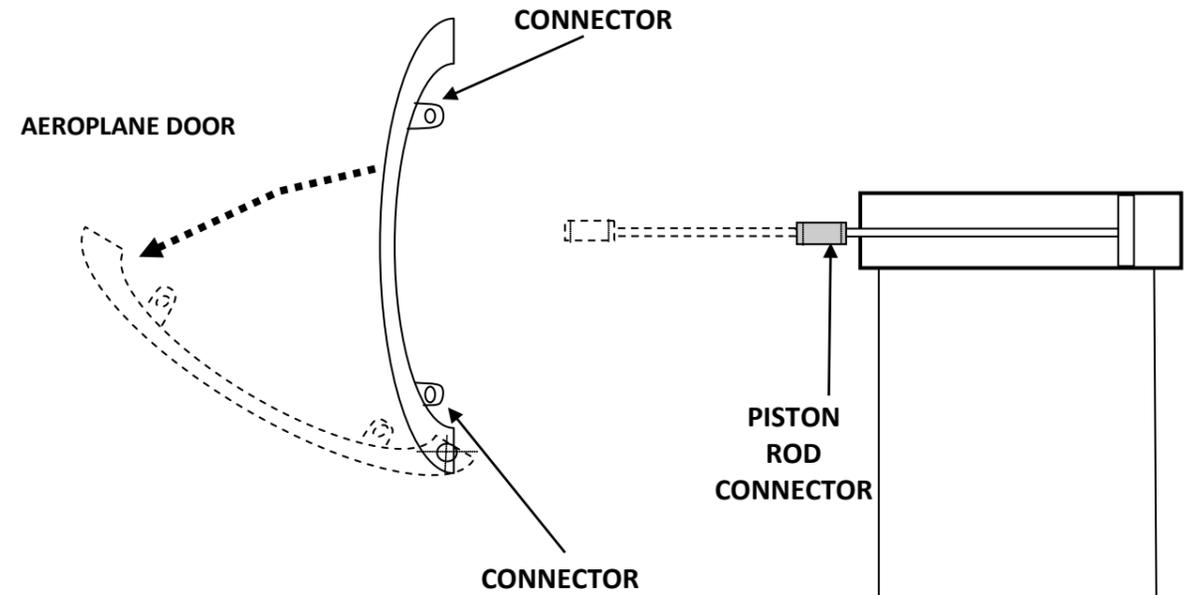
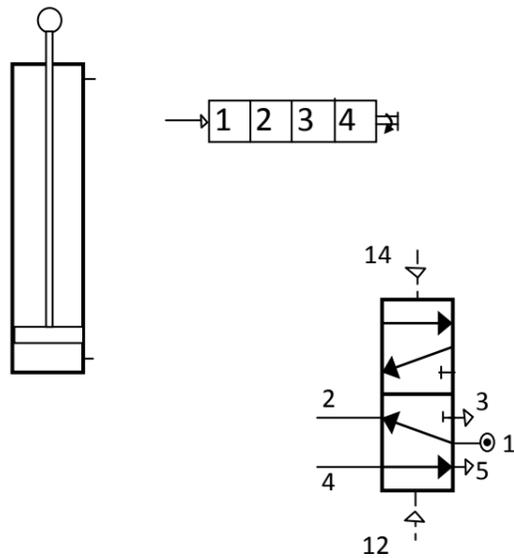
Pro forma answer page  
 (answer number 4(c))

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Double acting cylinder  
 outstrokes to push storage  
 tray upwards and goes  
 negative to return tray to  
 starting position.

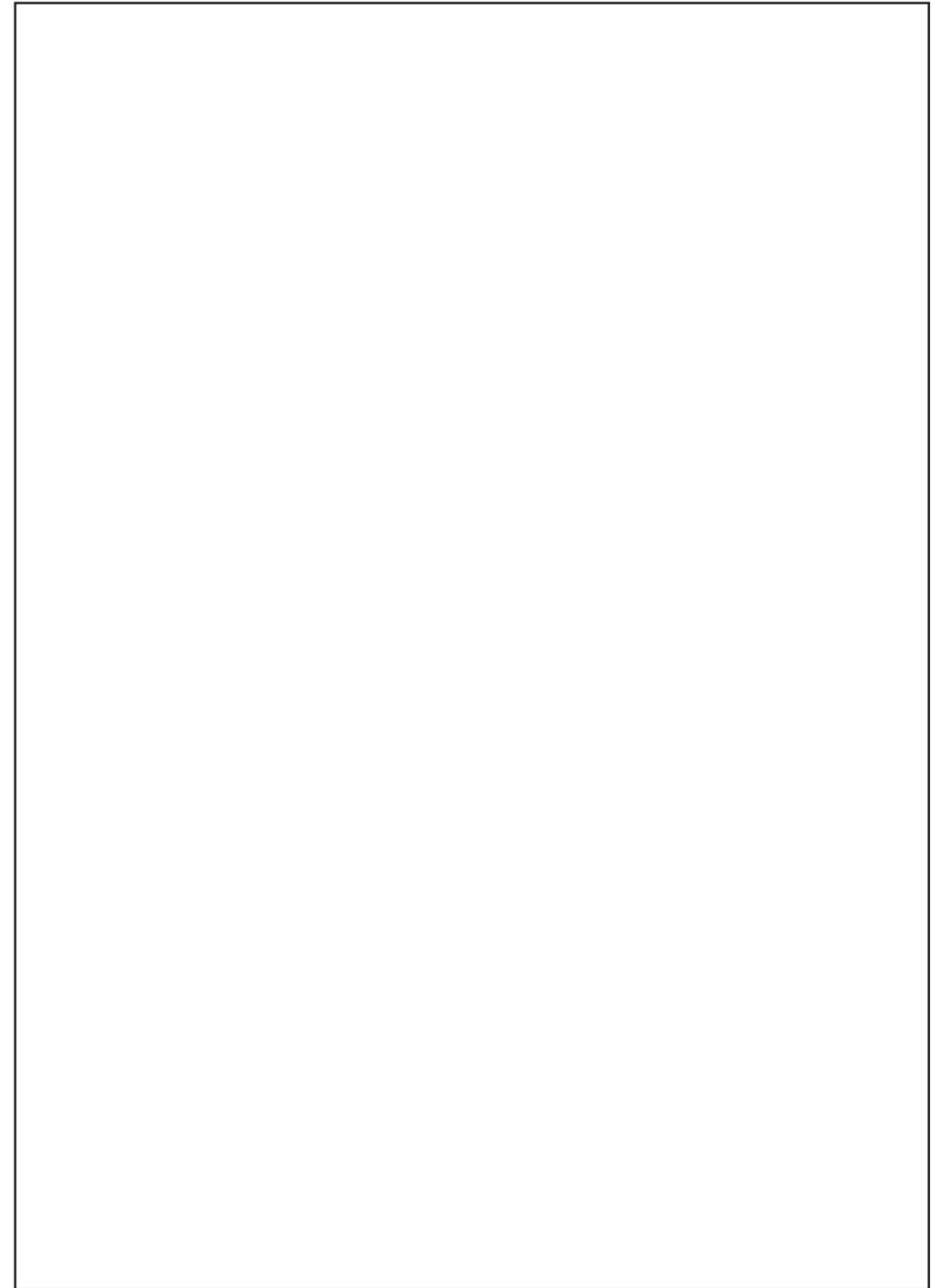


Pro forma answer page  
 (answer numbers 4(d)(i) and (ii))

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Template



**Pro forma answer page  
(answer number 5(h)(i) and (ii))**

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**Pro forma answer page  
(answer number 6(h))**