Rewarding Learning

ADVANCED
General Certificate of Education
January 2010

Technology and Design

Assessment Unit A2 3

assessing

Unit 6 – Systems and Control in Product Design

[A2V31]

A2V31

WEDNESDAY 20 JANUARY, MORNING

TIME

2 hours 30 minutes.

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 **three** questions.
Answer the **one** question in Section A and **either** the **two** questions in Section B **or** the **two** questions in Section C.
Answers to Questions **1(a)(v)** or **1(b)(v)**, Questions **5(b)(i)** and **(ii)** and **5(c)** should be made on the A3 pro forma answer pages provided.

INFORMATION FOR CANDIDATES

The total mark for this paper is 80, including a maximum of 4 marks for quality of written communication.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
At the conclusion of the examination, attach the A3 pro forma answer pages securely to the Answer Booklet with the treasury tag supplied.
You are provided with an insert sheet for Question **1**.
Do not write your answers on this insert.
A materials data sheet is provided.

Section A

This question is compulsory.

You are advised to spend 1 hour and 15 minutes on this section.
You are required to answer **either 1(a)** or **1(b)**.

For candidates studying Electronic and Microelectronic control systems answer part (a) using the pro forma (answer 1(a)(v)) and an answer booklet.

1 (a) The car wash shown on the insert in **Fig. 1(a)** provides the user with a quick "do it yourself" service available with a range of programs.
Inside the housing a prototype control system is to be designed to control the flow of water, shampoo and wax solution during a wash cycle.
The control system is to provide the following sequence of flows to the lance after a token has been inserted by the operator:
– water for initial wash, on for 45 seconds,
– water and shampoo for washing, on for 90 seconds,
– break of 45 seconds to use hand sponge,
– water to rinse, on for 60 seconds,
– wax solution, on for 60 seconds,
– water to rinse, on for 60 seconds.

(i) Determine if the sequence described above is that of an open-loop or closed-loop system. Give **one** main reason in support of your answer. [2]

(ii) Outline **two** main safety points that the manufacturer would need to consider regarding the control circuitry. [2]

(iii) The housing is formed from stainless steel sheets which are riveted to an internal box section frame. Briefly outline **two** main reasons why riveting would be used to join the steel to the frame. [2]

(iv) With reference to **Fig. 1(a)** briefly outline **two** main physical properties and **two** main mechanical properties which make stainless steel suitable for the housing. [4]

(v) On the pro forma provided use electronic and microelectronic circuit diagrams with annotation to produce a viable solution that will fulfil each of the specified points stated below.

(N.B. All brackets, housings, screws, nuts and bolts are not required.)

- Design a circuit that will detect the presence of a token and provide a 5 volt pulse for a duration of 50 milliseconds to start the car wash sequence. [5]

- The 24 volt solenoids are used to control the flow of water, shampoo and wax during the wash cycle. Assume a 5 volt 50 millisecond pulse is produced when a token is inserted. Design a PIC based circuit that will control the solenoids and associated indicator lamps, to provide the timing and sequence for a complete wash cycle. (Your answer **must** include a program.) [12]

- Design a circuit that will allow the 24 volt water heater to be used to heat the water flow if a hot wash cycle is selected. As a safety feature the heater must not operate in the event of a failure in the flow of water. [6]

- When the car wash is not in use the 12 volt indicator lamps are to flash in the repeating sequence: shampoo, rinse, wax. Design a circuit that will switch the indicator lamps in this sequence. [5]

For candidates studying Pneumatic and Mechanical control systems answer part (b) using the pro forma (answer 1(b)(v)) and an answer booklet.

(b) The car wash as shown on the insert in **Fig. 1(b)** provides the user with a quick "do it yourself" service available with a range of programs.
Inside the housing a prototype control system is to be designed to control the flow of water, shampoo and wax solution during a wash cycle. Each wash cycle is registered by the mechanical counter, this helps calibrate the volume of shampoo and wax used against the number of washes.
The control system is to provide the following sequence of flows to the lance after a token has been inserted by the operator:
– water for initial wash, on for 45 seconds,
– water and shampoo for washing, on for 90 seconds,
– break of 45 seconds to use hand sponge,
– water to rinse, on for 60 seconds,
– wax solution, on for 60 seconds,
– water to rinse, on for 60 seconds.

(i) Determine if the sequence described above is that of an open-loop or closed-loop system. Give **one** main reason in support of your answer. [2]

(ii) Outline **two** main safety points that the manufacturer would need to consider regarding the control circuitry. [2]

(iii) The housing is formed from stainless steel sheets which are riveted to an internal box section frame. Briefly outline **two** main reasons why riveting would be used to join the steel to the frame. [2]

(iv) With reference to **Fig. 1(a)**, briefly outline **two** main physical properties and **two** main mechanical properties which make stainless steel suitable for the housing. [4]

(v) On the pro forma provided use Pneumatic and Mechanical circuit diagrams with annotation to produce a viable solution that will fulfil each of the specified points stated below.

(N.B. All brackets, housings, screws, nuts and bolts are not required.)

- Design a suitable bearing and housing arrangement for the hose support bracket that will allow it to rotate. [5]

- Design and sketch a suitable mechanism for the drive shaft that will operate each of the three valves to achieve the sequence of flows stated above. Include an annotated sketch to show how the mechanism is attached to the shaft. [12]

- Design a gearbox using shafts A, B, C and D so that the output shaft D which is connected to the drive shaft rotates once during one complete wash program. Assume that the motor rotates at 48 rpm and only gears between 20 and 160 teeth can be used (state clearly the number of teeth to be used on each gear). [6]

- Design a suitable mechanism attached to the drive shaft that will turn the mechanical counter arm through 90 degrees to register one count after one complete rotation of the shaft. [5]

Section B

Electronic and Microelectronic Control Systems

Answer **both** questions in this section.

2 **Fig. 2** shows an incomplete counter circuit that has been designed to count the number of bottles from a production line to be packaged in a crate. Each crate holds six bottles. As the bottles pass and activate a microswitch, the number is displayed on an LED 7-segment display.

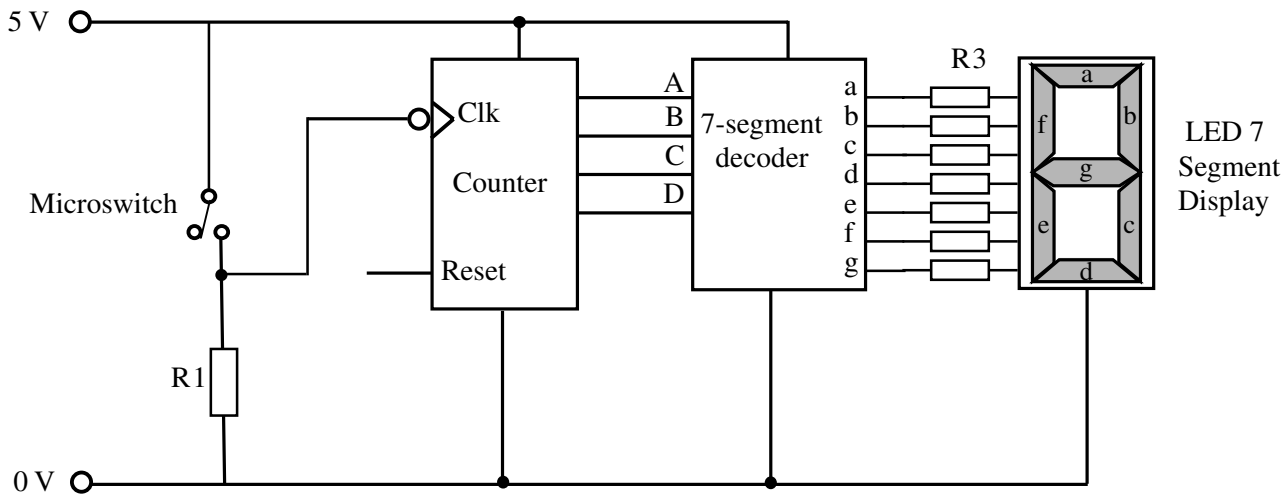

Fig. 2

(a) State the function of the resistor labelled R1 in **Fig. 2**. [1]

(b) The counter in **Fig. 2** operates when a falling edge trigger is received at the Clk input. Explain with the aid of a diagram what is meant by the term falling edge trigger. [2]

(c) Explain with the aid of a diagram how the counter could be used to count the bottles in batches of six, resetting after each batch. [4]

(d) During testing, it was found that the counter in **Fig. 2** was sometimes adding 2 or 3 to the count even though only one bottle was passing the microswitch. Explain a likely cause of this problem and suggest a modification to the circuit that would overcome this problem. [4]

(e) Draw a truth table for the 7-segment decoder showing the inputs A, B and C with the corresponding outputs a–g to the LED 7 segment display for 0 through to 5. [6]

(f) It has been proposed that the LED 7-segment display in **Fig. 2** be replaced by an LCD type. State **one** advantage and **one** disadvantage (excluding cost considerations) of LCD type displays compared to LED type displays. [2]

3 **(a)** The designers of a children's electronic game require a low cost power supply. A block diagram for an unregulated low voltage DC power supply is shown in **Fig. 3(a)**.

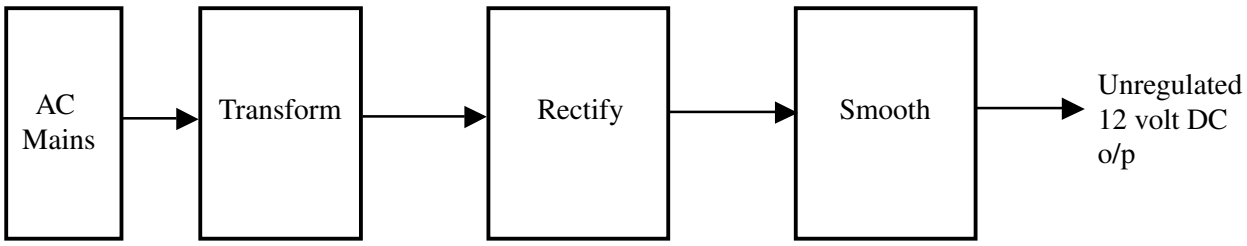

Fig. 3(a)

(i) Briefly explain the function of the Transform, Rectify and Smooth blocks shown in **Fig. 3(a)**. [3]

(ii) Sketch and label the output waveform for each block of the power supply shown in **Fig. 3(a)**. [4]

(b) **Fig. 3(b)** shows a simple voltage regulator based on a Zener diode that is to be connected to the unregulated power supply shown in **Fig. 3(a)** in order to provide a constant 6 volt supply.

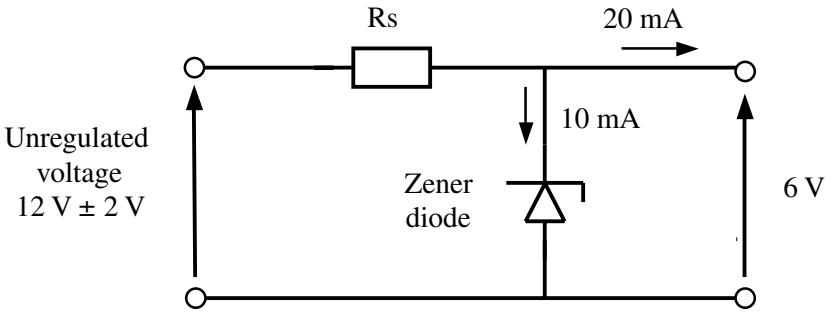

Fig. 3(b)

(i) Explain how the output voltage supplied to the electronic game will remain constant despite fluctuations in the input voltage from the unregulated supply. [1]

(ii) An output current of 20 mA is required to operate the electronic game. Calculate an appropriate value for the Resistor Rs in **Fig. 3(b)**. [2]

(c) The children's electronic game is to include a microphone to detect sound. **Fig. 3(c)** shows a microphone and op amp.

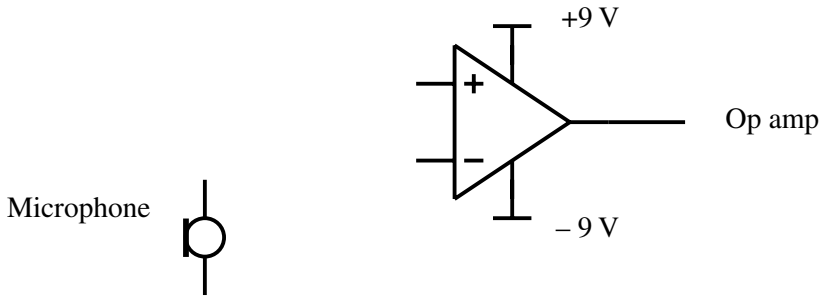

Fig. 3(c)

(i) With the aid of a diagram, briefly explain the operation of a ceramic type microphone. [3]

(ii) A non-inverting amplifier is required to amplify the microphone voltage. Draw a suitable amplifier circuit based on the op amp shown in **Fig. 3(c)** and suggest suitable values for resistors R1 and Rf to achieve a gain of 100 given that gain = $1 + \frac{Rf}{R1}$. (R1 and Rf are used to provide feedback.) [4]

(iii) Briefly explain how a signal generator and an oscilloscope can be used to check the voltage gain of the amplifier in **3(c)(ii)**. [2]

Section C

Pneumatic and Mechanical Systems

Answer **both** questions in this section.

4 **Fig. 4** shows part of a prototype drive system used to operate a conveyor belt in a mass production line.

(i) Multigrade oil is often chosen to lubricate gears. Briefly outline its main characteristics. [2]

(ii) Calculate the output torque on the auxiliary output shaft if the input torque on gear **C** is 150 N. [2]

(iii) Using an annotated sketch, name and draw a mechanism used to transfer the rotary motion from the motor to gear **C** via shaft **P** at an even rate. [3]

(iv) Calculate the overall velocity ratio from gear **C** to the wormwheel **L**. [4]

(v) The bearings on the auxiliary output shaft experience both axial and radial loadings. Using an annotated sketch, outline a suitable bearing and housing arrangement to be used in the location indicated. [4]

(vi) Calculate the power supplied by the motor to shaft **P**, rotating it at an angular speed of 240 rev/min with a torque of 200 Nm. [2]

(vii) Block **W** on the conveyor belt has a mass of 5 kg. The conveyor belt is not horizontal and the block moves through a vertical height of 1 m over this distance. Assume g = 9.81 m/s^2. Calculate the gain in potential energy. [2]

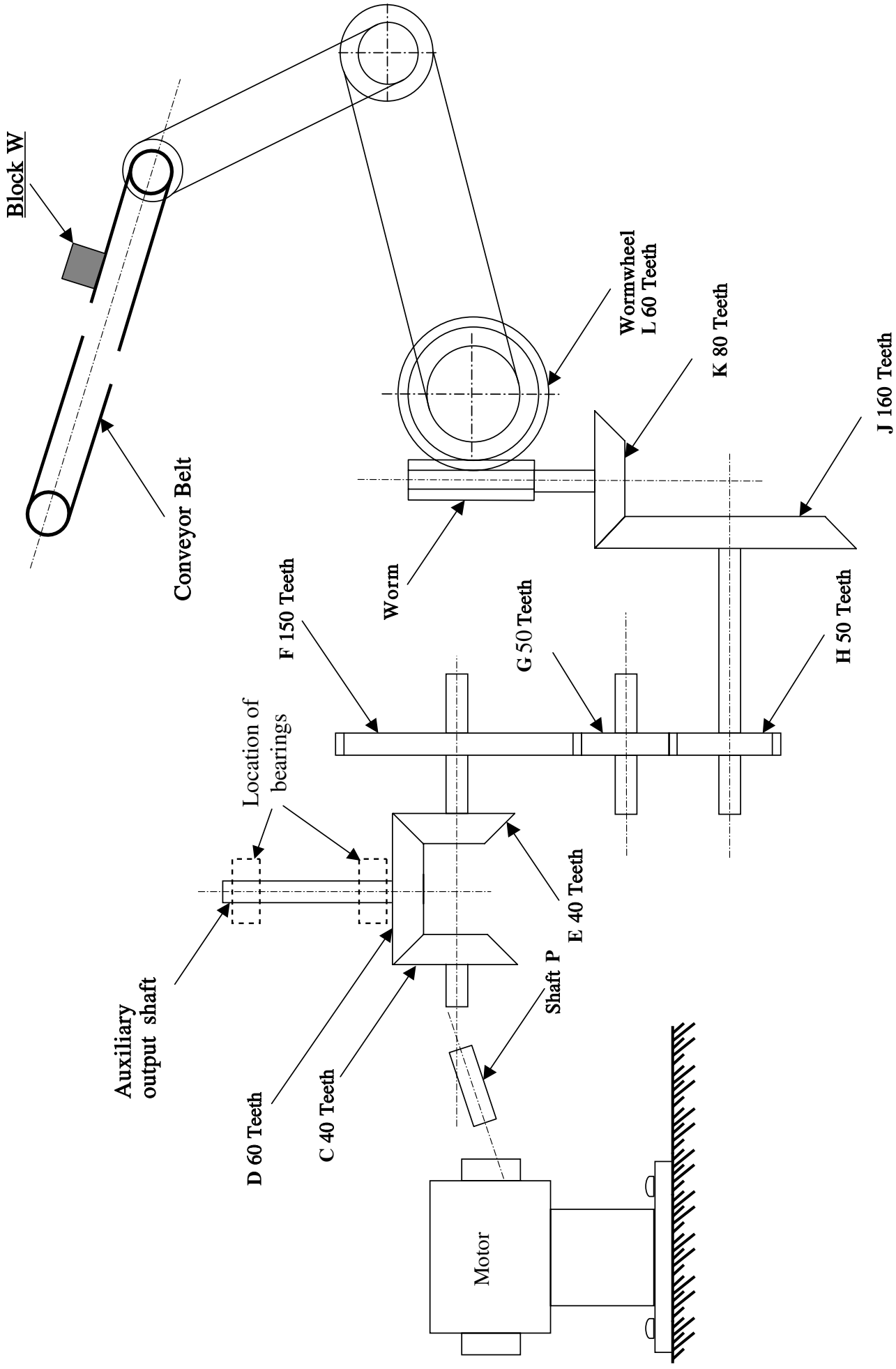
Block W
Conveyor Belt
Worm
Wormwheel
L 60 Teeth
K 80 Teeth
J 160 Teeth
F 150 Teeth
G 50 Teeth
H 50 Teeth
Location of
bearings
E 40 Teeth
Auxiliary
output shaft
Shaft P
D 60 Teeth
C 40 Teeth
Motor

Fig. 4

5 **Fig. 5(a)** shows parts of a pneumatic based prototype box printing station.

(a) **(i)** Briefly describe a pneumatic component which could be used on cylinder **D** to hold and release the boxes. [1]

(ii) Briefly explain **one** advantage and **one** disadvantage associated with the use of interlocking in sequential circuits. [2]

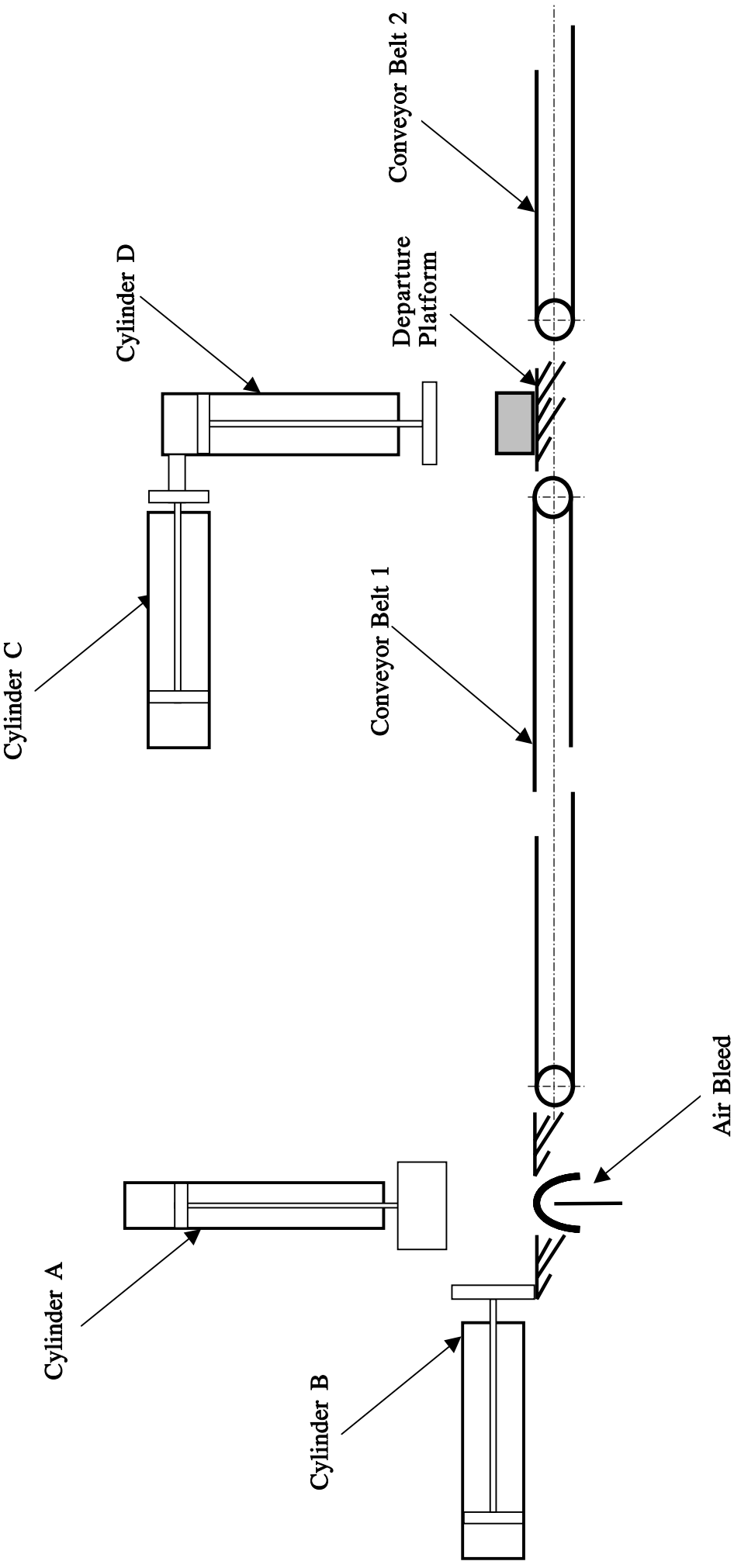
Conveyor Belt 2
Cylinder D
Departure Platform
Cylinder C
Conveyor Belt 1
Air Bleed
Cylinder A
Cylinder B

Fig. 5(a)

(b) A box travels along to a further manufacturing stage which utilises the incomplete circuit shown in **Fig. 5(b)**. The circuit when complete is expected to perform the following operation:
S1 is pressed until cylinder **X** outstrokes, which in turn activates an outstroke of cylinder **Y**. After a short delay in time, cylinder **Z** outstrokes, pressing **S2** which enables it to instroke again.

(i) On the pro forma provided (Pro forma Answer No. **5(b)(i) + (ii)**), complete the circuit to achieve the desired circuit operation. [2]

(ii) As a safety feature on the pro forma provided (Pro forma Answer No. **5(b)(i) + (ii)**), show how cylinder **Z** can be de-activated pneumatically. [2]

With regard to **Fig. 5(a)**.

(c) The following sequence begins once a box is placed over the air bleed:

- Cylinder A outstrokes **slowly** to print a design on the box.
- Cylinder A instrokes.
- Cylinder B outstrokes **slowly** to push the box onto conveyor belt 1.
- Cylinder D outstrokes in order to lift the box.
- Cylinder C outstrokes to move cylinder **D** above conveyor belt 2 where it releases the box.
- Cylinder C instrokes.
- Cylinder B instrokes.
- Cylinder D instrokes.

On the pro forma provided (Pro forma Answer No. **5(c)**, draw a suitable interlocking/ cascade sequential circuit to achieve the desired sequence. [7]

(Your answer does not need to include details of how the box is held and released by cylinder D.)

(d) Cylinder **Y** has a piston diameter of 40 mm and operates with an air pressure of 0.5 N/mm^2. Cylinder **Z** has a piston radius of 25 mm and operates with an air pressure of 1 N/mm^2. Calculate the piston rod diameter required for cylinder **Z** to instroke with three times the outstroke force of cylinder **Y**. Please assume $\pi = 3.14$. [5]

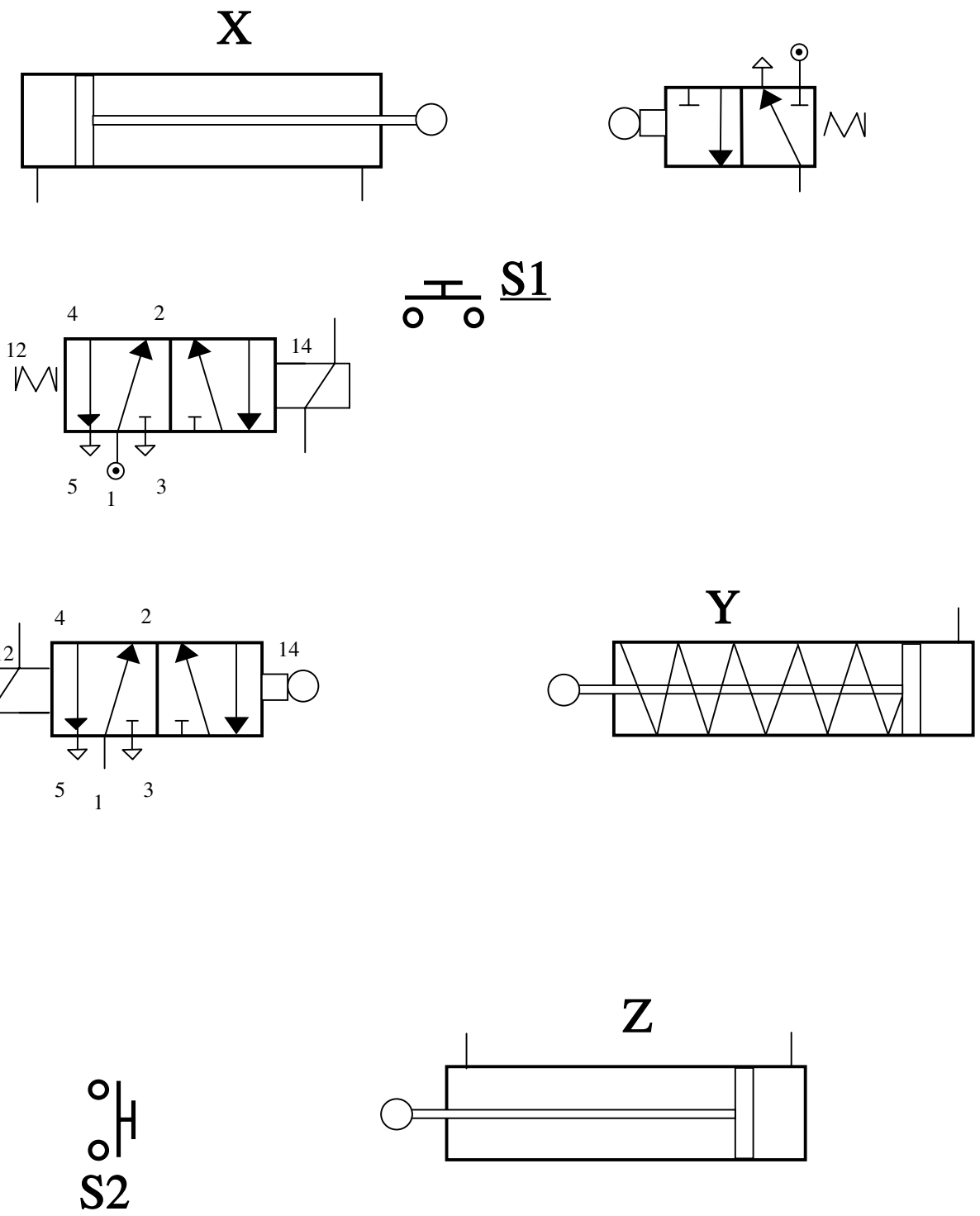

Fig. 5(b)

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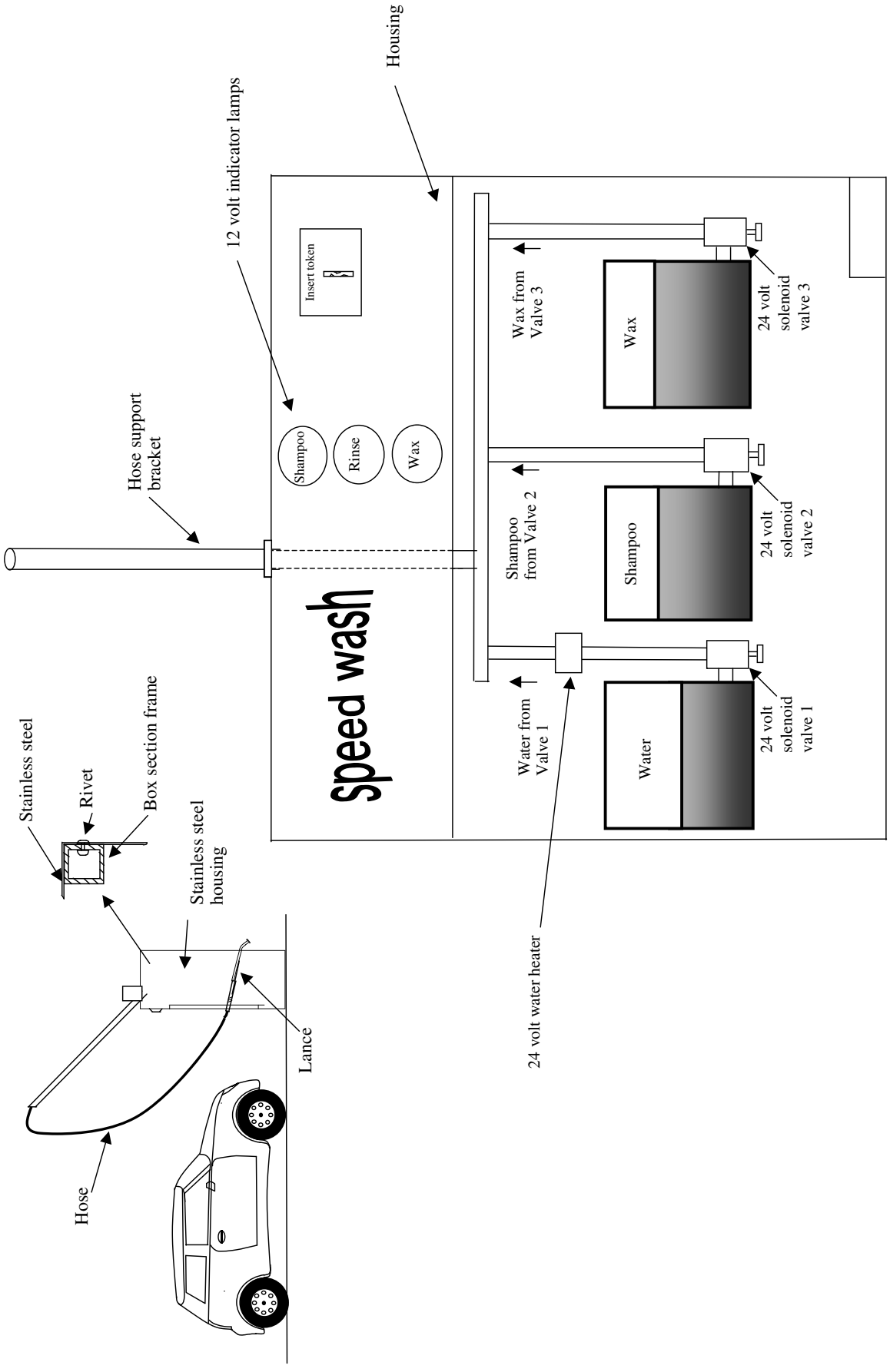
(for use with Question 1(a))

Fig. 1(a)

For candidates studying Electronic and Microelectronic control systems.



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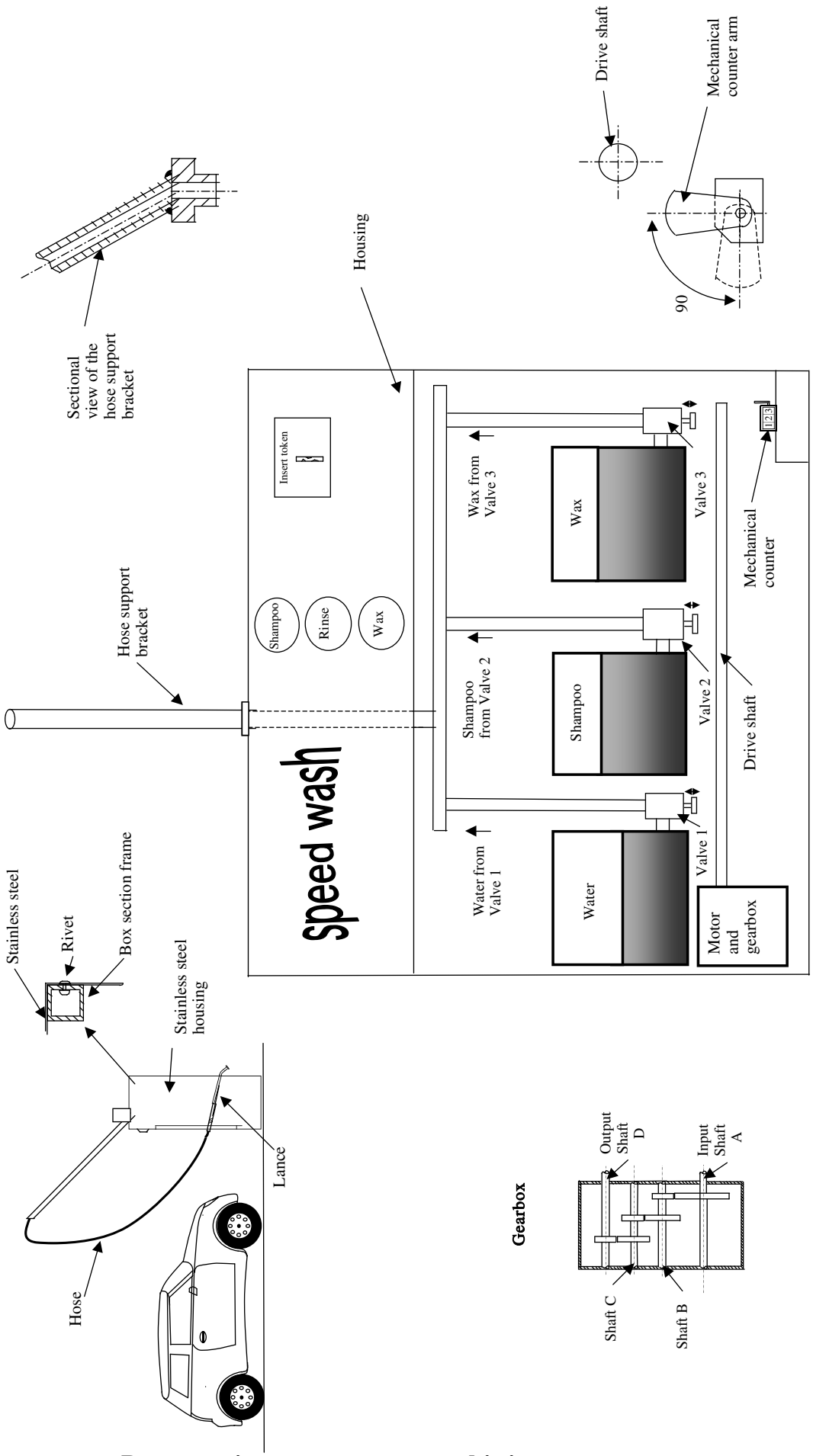
(for use with Question 1(b))

Fig. 1(b)

For candidates studying Pneumatic and Mechanical control systems.



Do not write your answers on this insert

Question No. 1(a)(v) or 1(b)(v)

ADVANCED LEVEL TECHNOLOGY AND DESIGN
Assessment Unit A2 3 Unit 6
January 2010

Centre Number

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Candidate Number

Pro forma answer page
(answer number 1(a)(v) or 1(b)(v))

A2V31IN2

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

ADVANCED LEVEL TECHNOLOGY AND DESIGN
Assessment Unit A2 3 Unit 6
January 2010

Centre Number

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Candidate Number

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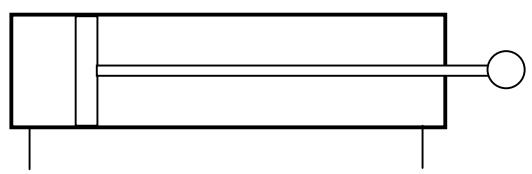
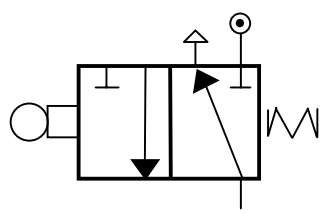
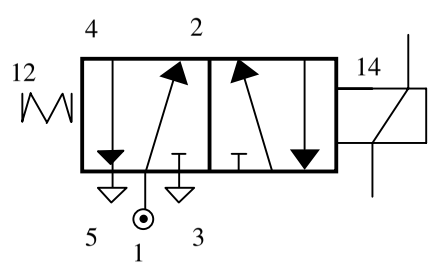
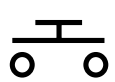
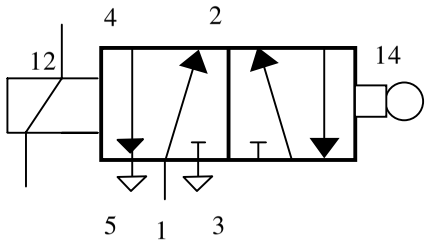




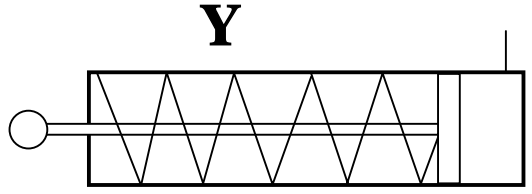


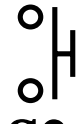


S1



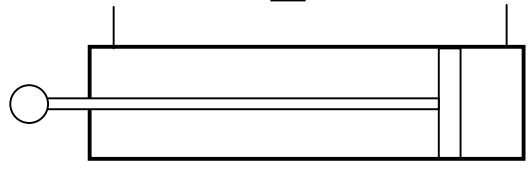
Y





S2

Z



Pro forma answer page
(answer number 5(b)(i) and (ii))

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Question No. 5(c)

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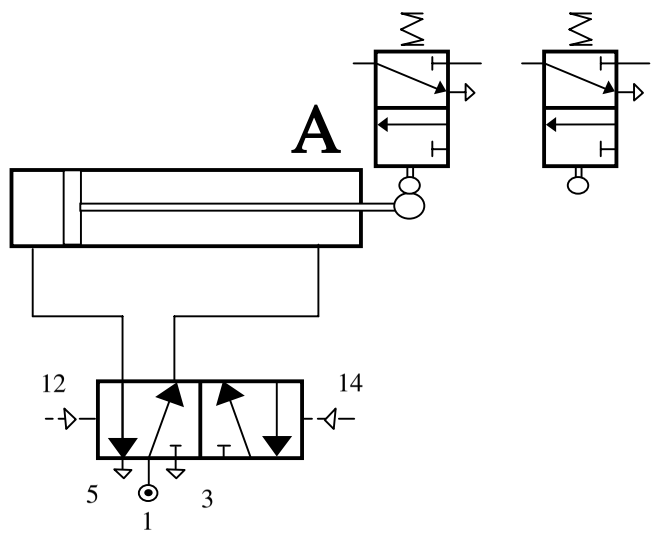

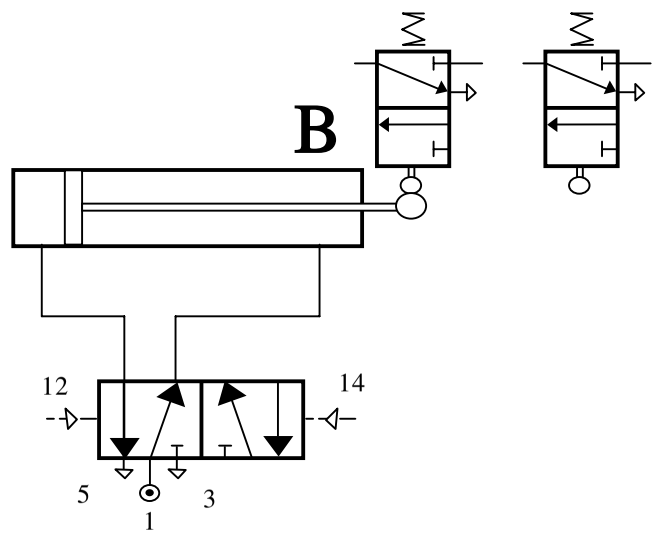

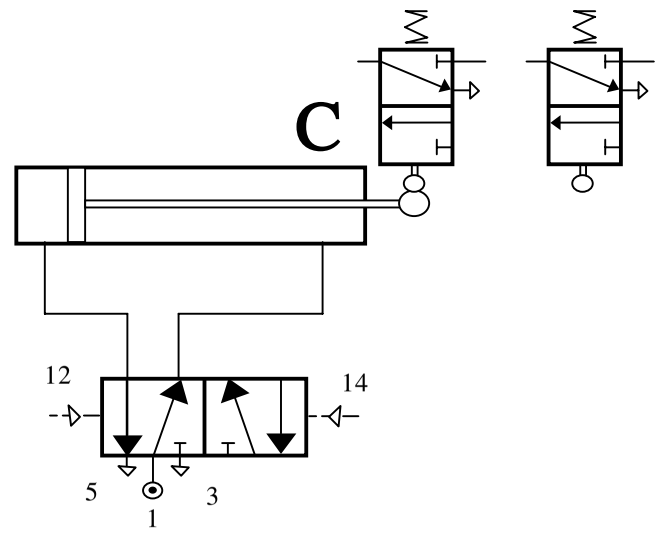

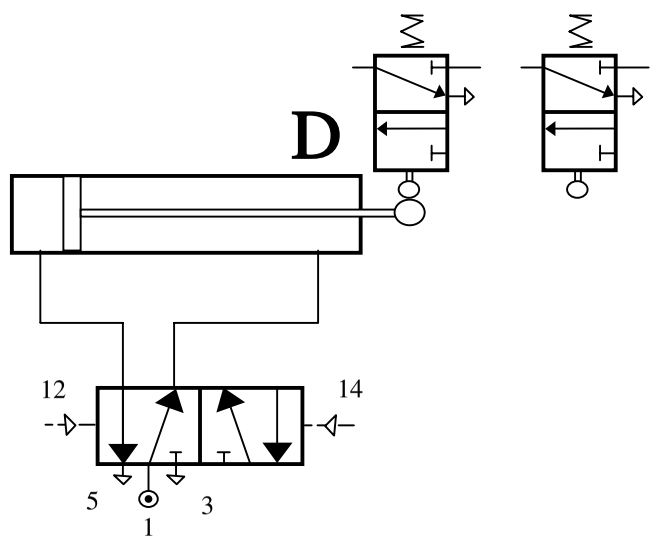

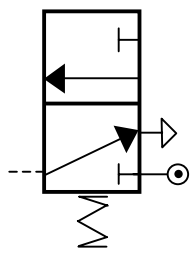

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