Rewarding Learning

ADVANCED
General Certificate of Education
2015

Technology and Design

Assessment Unit A2 1
assessing
Systems and Control
and
Product Design

[AV211]

TUESDAY 2 JUNE, 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 **two** questions from either Section A, Section B or Section C.
Answers to questions **1(e)**, **2(e)**, **4(c)**, **4(d)**, **5(f)(i)** and **(ii)** and **6(i)(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 **1(f)**, **3(c)** and **5(c)**.
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)** A diagram representing a circuit used to control the backlight brightness of an LCD is shown in **Fig. 1(a)**. The brightness of the backlight is adjusted by means of a variable resistor VR.
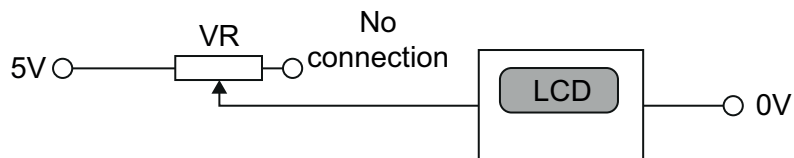
Fig. 1(a)

   (i) Give **one** main advantage of using an LCD as a display. [1]

   (ii) State if the type of control shown in **Fig. 1(a)** can be considered as a continuous or on/off system and briefly justify your answer. [2]

   (iii) The LCD backlight is connected to a 5 volt power supply using a 220 ohm variable resistor in **Fig. 1(a)**. Assuming there is a 2.5 V voltage drop across the backlight, calculate the power dissipation of the variable resistor when adjusted to its mid position. [2]

(b) **Fig. 1(b)** shows a seven segment LED display which can be used as an alternative to an LCD. The seven segment LED display is a common cathode type and is connected to a decoder through resistors R_1 to R_7.
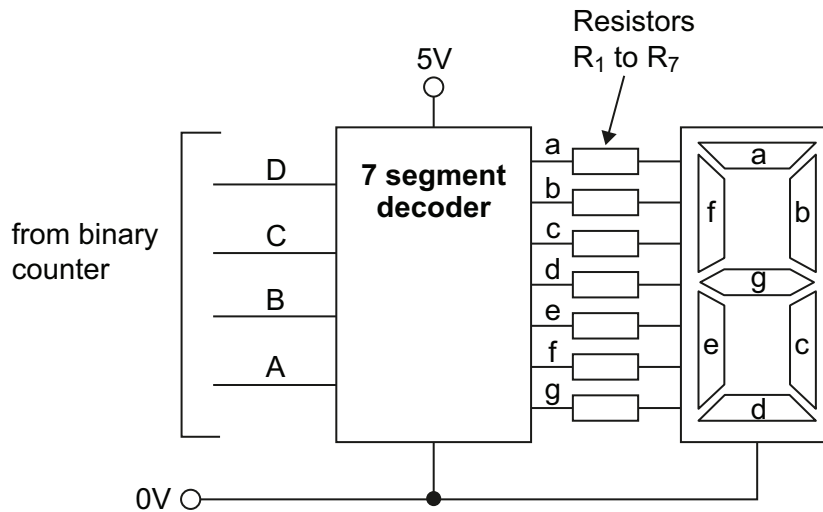

Fig. 1(b)

(i) State **one** main advantage other than cost of using an LED seven segment display compared to an LCD. [1]

(ii) Draw a circuit diagram to show how the LEDs are connected in a common cathode seven segment display. [2]

(iii) Calculate a suitable value for resistors R_1–R_7 in **Fig. 1(b)** where each LED segment requires a maximum current of 16 mA when illuminated. Assume that the forward voltage of each LED segment is 2.2 volts. [2]

(c) Part of an incomplete logic truth table for the 7 segment decoder in **Fig. 1(b)** is shown in **Fig. 1(c)** below. It shows inputs **A**, **B**, **C**, and **D** (where A is the least significant bit) with the corresponding outputs a to g for two of the displayed numbers. Determine the missing logic values. (Do not provide your answer on **Fig. 1(c)**). [2]

| A	B	C	D	a	b	c	d	e	f	g
1	0	1	0							
				1	0	1	1	1	1	1

Fig. 1(c)

(d) An LED display is to be used to show the speed of a mountain bicycle. A prototype system to measure the speed of the bicycle is shown in **Fig. 1(d)**. The system makes use of two small notches cut into the existing brake disc which is attached to the axle of the wheel. When the axle rotates the notches on the disc are detected by means of an infrared transmitter and phototransistor built into the brake caliper.
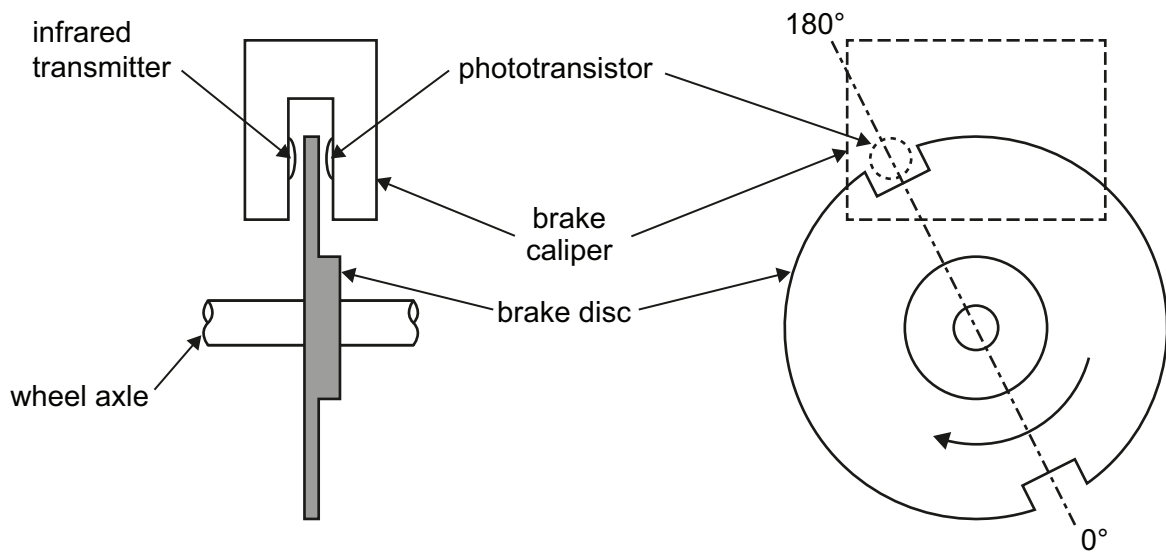
Fig. 1(d)

(i) Briefly describe **one** main advantage and **one** main disadvantage of using an infrared transmitter and phototransistor for the application outlined above. [2]

(ii) Using an annotated circuit diagram, show how an infrared transmitter and a phototransistor could be connected to a 5 volt power supply to provide a pulse with the following characteristics:
- low/zero voltage when the brake disc blocks the infrared transmitter
- high/5 volts when the notch is aligned with the transmitter and receiver. [4]

(iii) Draw a graph with labelled axes to show how the output voltage from your circuit in part **(d)(ii)** above changes as the disc rotates through 360 degrees from the position shown in **Fig. 1(d)**. [3]

(e) Part of a proposed circuit design for the bicycle speedometer is shown in **Fig. 1(e)** where the pulses from the phototransistor in **Fig. 1(d)** are to be counted for a period of 1 second and the speed in kph (kilometres per hour) is then to be displayed for 2 seconds on two LED seven segment displays. i.e. the display is effectively 'refreshed' every 3 seconds. During testing it was noted that when the brake disc rotated at 1 revolution per second the corresponding bicycle speed was 6 kph.
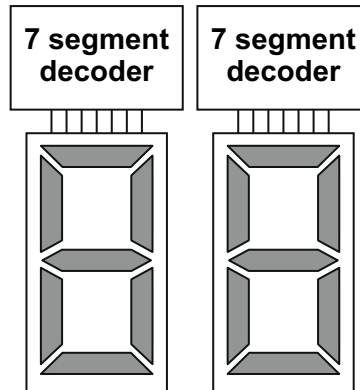

Fig. 1(e)

Using annotated electronic circuit diagrams on the blank pro forma provided (answer number **1(e)**) design a circuit for the bicycle speedometer that will repeatedly detect the pulses from the phototransistor for 1 second and display the speed in kph for 2 seconds. (If your solution is PIC based it should be accompanied by a flow chart program.) [10]

(f) When selecting the infrared transmitter and phototransistor to act as a sensor to detect the rotation of the brake disc in **Fig. 1(d)** the designer considered a number of factors, e.g. whether a contact or non contact sensor would best suit the application. Discuss **three** other main factors that designers must consider when choosing the most suitable sensor for any particular application. Provide **two** different specific examples, other than the one shown in **Fig. 1(d)** that clearly illustrate how these factors influence the selection of a sensor. [5]

Quality of written communication [4]

2 The voltage divider circuit shown in **Fig. 2(a)** is to be used as part of a circuit for measuring the air temperature in a greenhouse. The resistance/temperature characteristic for the thermistor Rt is also shown.
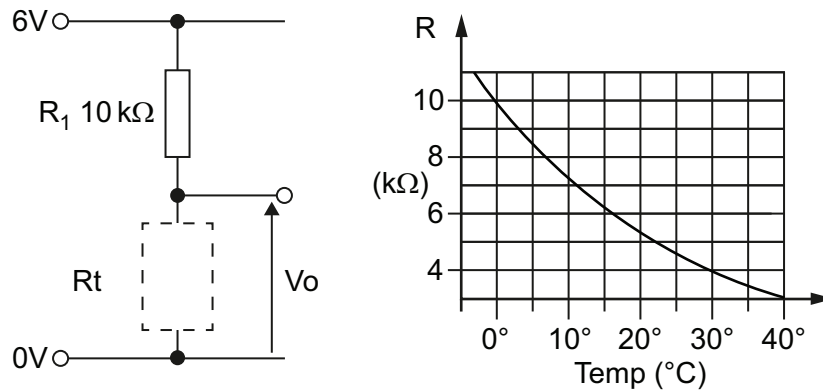
Fig. 2(a)

(a) (i) Draw the circuit symbol for the thermistor referred to in **Fig. 2(a)**. [1]

(ii) Explain the purpose of a voltage divider circuit. [2]

(iii) Sketch a graph with labelled axes showing how the output Vo in **Fig. 2(a)** varies as the temperature changes. [2]

(iv) If the air temperature in the greenhouse varies between 10°C and 30°C on a given day, calculate the corresponding voltage range for Vo in **Fig. 2(a)**. [2]

(b) A greenhouse temperature display is to be made by using the voltage Vo from the voltage divider in **Fig. 2(a)** connected to a voltmeter by means of an amplifier based on an op amp as shown in **Fig. 2(b)**. It is required that the voltage displayed by the meter, in volts, should represent the temperature in °C. During tests it was noted that Vo ranged from 4 volts at 0°C to 2 volts at 40°C.
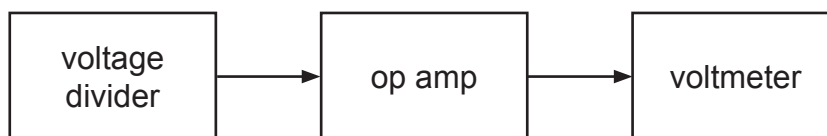
Fig. 2(b)

Draw and label a differential amplifier to meet this requirement showing clearly how the voltage divider and voltmeter would be connected. Also determine suitable values for Rf and Ri, where Rf is the feedback resistor and the gain for a differential amplifier is Rf/Ri. [6]

(c) A water storage tank used to irrigate the greenhouse is filled through a solenoid operated inlet valve as shown in **Fig. 2(c)**. When the water in the tank falls below a certain level the inlet valve is opened and the tank is refilled. A float arrangement operates upper and lower limiting microswitches which are also shown in **Fig. 2(c)**.
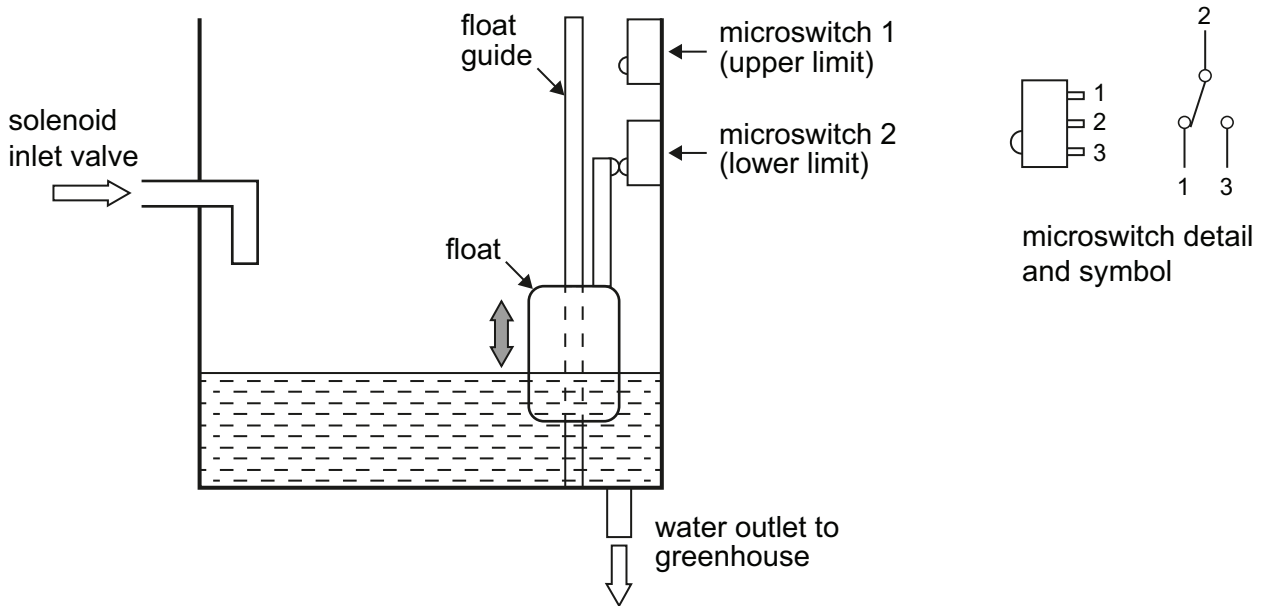
Fig. 2(c)

(i) Show with the aid of an annotated circuit diagram how the microswitch shown in **Fig. 2(c)** could be used in conjunction with other components to provide a logic '1' input to a digital input of a PIC when operated by the float. [2]

(ii) Show with the aid of an annotated circuit diagram, how a 24 volt solenoid, in conjunction with other components, could be connected to the output of a PIC to enable it to be opened by a logic '1' on a digital output. [2]

(iii) A PIC with two digital inputs (I/P1 and I/P2) and one digital output (O/P1) is to be employed to control the solenoid inlet valve on the water storage tank in **Fig. 2(c)**. Assume that when operated the microswitches provide a logic '1' at the inputs of the PIC and that the solenoid is connected to the output of the PIC to enable it to be opened by a logic '1' on the output.
Using the minimum number of commands, write a flow chart program that will refill the tank when necessary, i.e. when the lower limiting microswitch is operated. (assume microswitch 1 is connected to I/P1 and microswitch 2 is connected to I/P2) [4]

(d) A logic circuit used to control artificial lighting in the greenhouse has logic inputs from three environmental sensors S1, S2 and S3 as shown in **Fig. 2(d)**.
A logic '1' from the output Q of the logic circuit will switch the artificial lighting on. The lighting must be switched on only under the following conditions: S1 AND S3 only high, S1 AND S2 only high, S2 AND S3 only high, S2 only high.
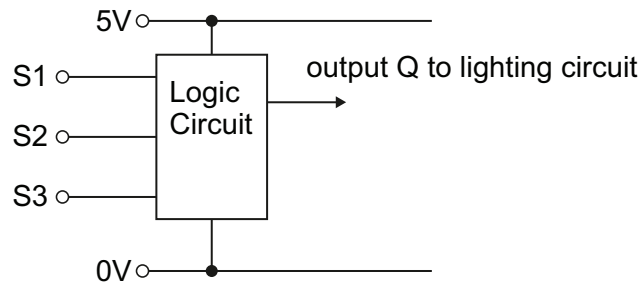

Fig. 2(d)

(i) Draw a truth table showing the logic inputs S1, S2 and S3 from the sensors and the output Q to control the artificial lighting. [4]

(ii) Use a Karnaugh Map to determine a minimised logic expression for the output Q. [3]

(iii) Draw a logic circuit that will produce the required output Q. [2]

(e) A humidity sensor and DC motor are shown in **Fig. 2(e)**. The sensor provides an analogue output voltage which is directly proportional to the humidity in a greenhouse. The output voltage of the sensor varies from 0 to 5 volts as the humidity ranges from 0% to 100%. The 12 volt DC motor is to be used to drive a fan in order to ventilate the greenhouse to reduce humidity levels when necessary. The DC motor is to be run at high speed or low speed as required.
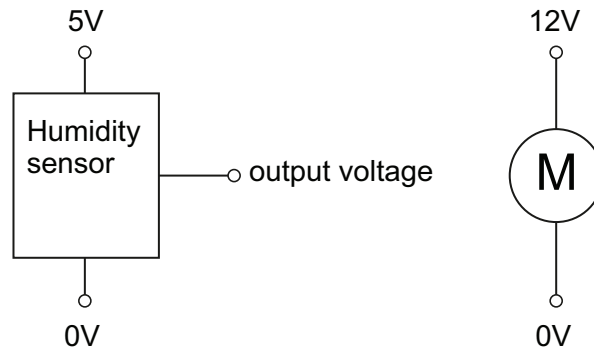
Fig. 2(e)

A PIC with an analogue input is to be used to periodically 'read' the humidity sensor and in turn control the DC motor. The voltage range of the analogue input is 0 to 5 volts and the corresponding digital range is 0 to 255.

Using annotated electronic circuit diagrams (on the blank pro forma provided (answer number **2(e)**) design a PIC based circuit and associated flow chart program that will fulfil the following:

• Check the humidity level every 4 minutes.

• If the humidity level is equal to or above 60%, switch the fan on at full speed until the humidity level is equal to or below 40% at which point the fan should switch to low speed.

• If the humidity level is equal to or below 20% the fan should switch off.   [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   **Fig. 3 (a)(i)** shows an image of a prototype helicopter that can be used to transport people. The helicopter contains a range of mechanical and hydraulic components and is powered by an engine.

© Svetlana Polushkina/ iStock / Thinkstock
Fig. 3(a)(i)

(a) (i) Outline **two** main safety issues associated with mechanical systems. [2]

(ii) The prototype helicopter uses a taper bearing to support the transmission shaft on the main rotor. In your answer booklet draw a suitable taper bearing arrangement for the transmission shaft shown in **Fig. 3(a)(ii)**. Please note that significant radial and axial forces are present. Show how the bearing is secured in position and includes provision for lubrication. [5]
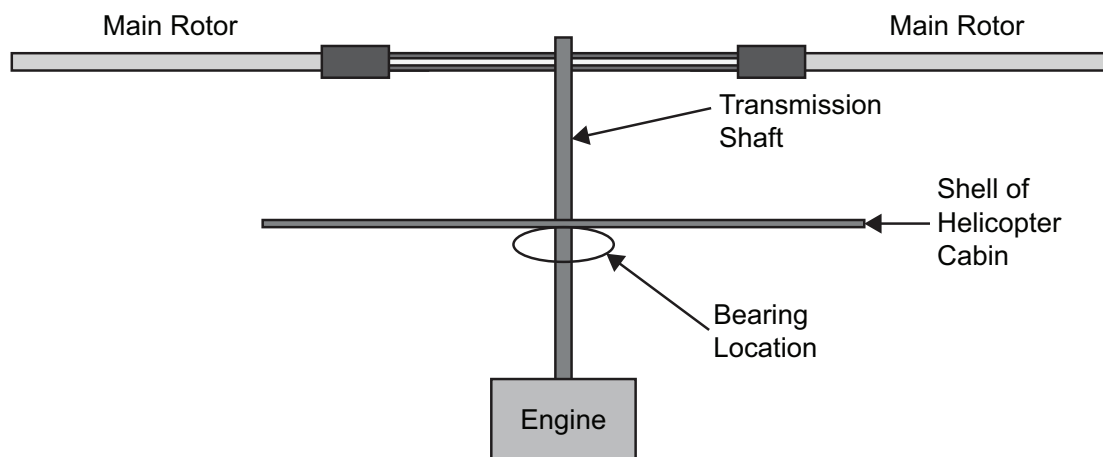

Fig. 3(a)(ii)

(iii) Briefly describe **two** main characteristics associated with using a roller bearing in comparison to a self-aligning bearing. Exclude any reference to radial and axial loads. [2]

(b) (i) The prototype helicopter is transported for maintenance on a trolley. A cantilever brake is engaged on the trolley as a means of control. In your answer booklet draw an annotated sketch outlining the main features of a typical cantilever braking system that could be used on the trolley. [3]

(ii) The winch shown in **Fig. 3(b)(ii)** has been added to the helicopter for assisting with lifting loads. The winch hook lifts a load with a mass of 65 kg up a vertical height which gains 7021.3 J in potential energy before coming to rest. Calculate the vertical height the load is lifted. Assume $g = 9.82$ m/s^2. [3]
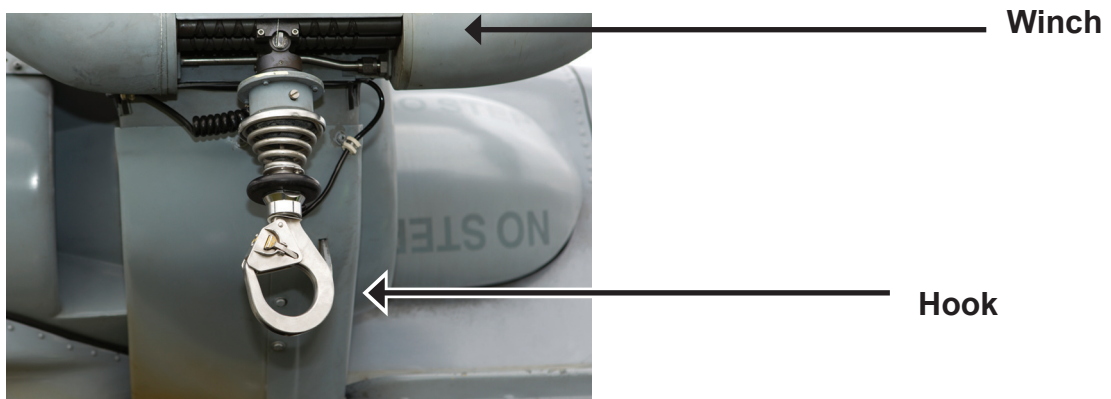
© Edsisonphotos/ iStock / Thinkstock

Fig. 3(b)(ii)

(iii) Calculate the minimum power to be provided to the winch system in order for the winch output shaft to lift the hook 3 metres in 30 seconds if the gravitational force on the hook is 800 N. Assume a 25% loss of power due to friction. [3]

(iv) The output torque from the main transmission shaft is 260 N m. Assuming no power loss, calculate the power from the main transmission shaft of the helicopter if it rotates at 1400 rev/min. [3]

(c) Refuelling of helicopters and light aircraft is often supplied by a small tanker lorry. The lorry contains a clutch to transmit motion from the crankshaft in the engine to the driveshaft.

Discuss **one** main advantage and **one** main disadvantage of each of the following clutches: diaphragm and centrifugal. Justify the choice of hydraulic activation as a method employed to activate the lorry clutch. [5]

Quality of written communication [4]

(d) In your answer booklet design, draw and annotate a mechanical system that would achieve each of the following requirements:

(i) A means by which the lid of the first aid box stored on the helicopter can be secured down as shown in **Fig. 3(d)(i)**. The mechanism must be **quick release**, attached to the main casing and must be secured within the locking area. [4]
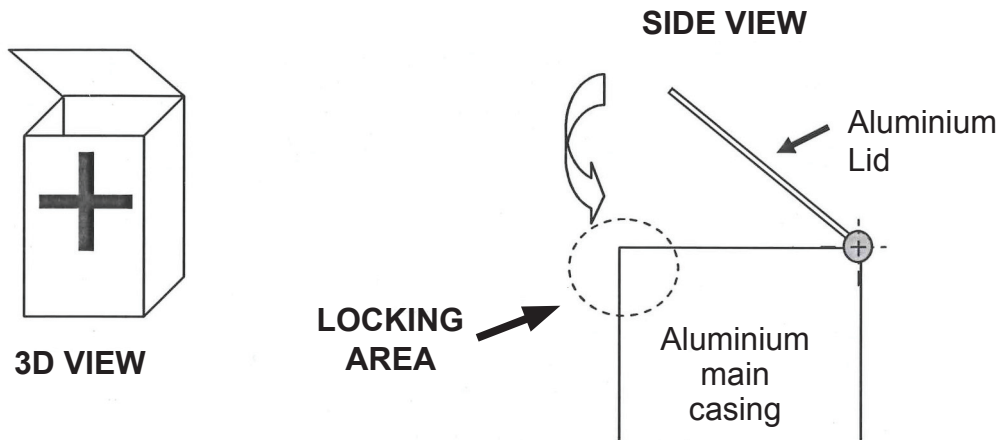
SIDE VIEW

Fig. 3(d)(i)

(ii) A means of enabling the platform in **Fig. 3(d)(ii)** to be raised and lowered to a suitable height by the operator when carrying out routine maintenance on engine components on the helicopter. The mechanism must be manually operated, secured underneath the platform and have a suitable means of locking the platform at a set height. Your solution must be attached to the pivot points and base. [6]
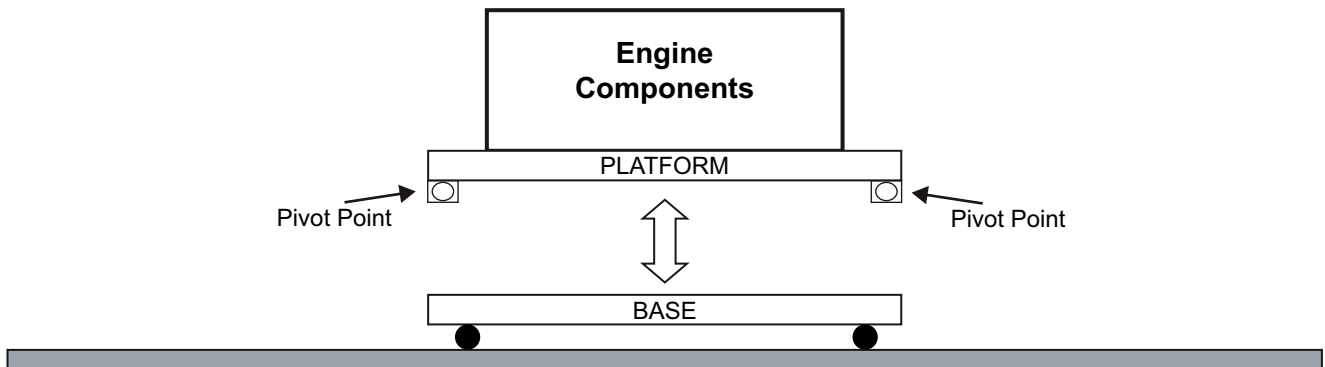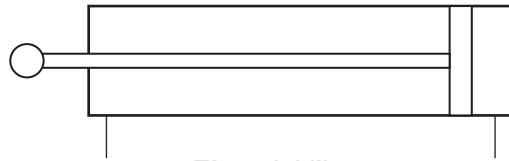

Fig. 3(d)(ii)

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(Questions continue overleaf)

4   (a) (i) The double acting cylinder in **Fig. 4(a)(i)** has a stroke length of 400 mm and is calculated to exert a force during the outstroke of 600 N. Calculate the work done.   [1]


Fig. 4(a)(i)

(ii) Open and closed loop systems are used in pneumatic circuits. With reference to a specific pneumatic example of your choice, distinguish between an open and closed loop system.   [2]

(iii) The double acting cylinders B1, B2, B3 and B4 in **Fig. 4(a)(ii)** operate with an air pressure of $0.4\,N/mm^2$ with each producing a force of 1538.6 N during the outstroke. It is intended to replace B1, B2, B3 and B4 with one large double acting cylinder. Calculate the piston radius of this replacement double acting cylinder which will operate at the same air pressure and produce the same overall force. Assume $\pi = 3.14$.   [3]

B1   **B2**   **B3**   **B4**
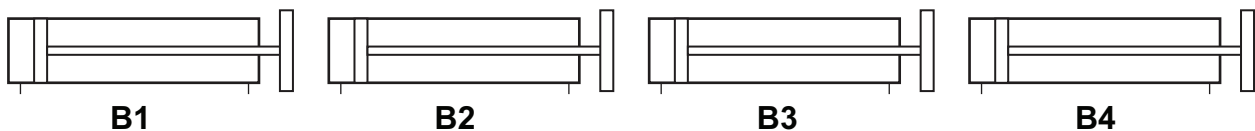
Fig. 4(a)(ii)

(b) (i) With reference to the data below calculate the air consumption in litres for the double acting cylinder shown in **Fig. 4(b)(i)** below for one complete cycle: [5]

D = 80 mm
S = 300 mm
d = 25 mm
Working Pressure = 5 Bar
Assume $\pi = 3.14$
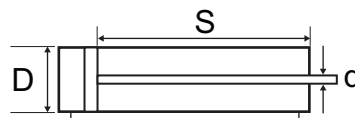
Fig. 4(b)(i)

(ii) Proximity sensors are used on a range of pneumatic systems. Explain the principle of operation of a proximity sensor.   [2]

(iii) O-rings are used to seal the piston inside a double acting cylinder.
Give **two** main advantages of using O-rings as seals.   [2]

(c) Pro forma **4(c)** shows a pneumatic system used in a soft drinks management system. On the pro forma provided (answer number **4(c)**) draw a suitable sequential pneumatic circuit to achieve the desired sequence outlined. The sequence must be completed as follows:

- The start valve is activated to begin the sequence. With a keg in position cylinder A will go positive to place the keg below TANK 1. This will activate the air bleed to make cylinder W go negative, emptying some of the contents of TANK 1 into the keg. Following detection by the 3/2 valve a time delay will begin and cylinder W will go positive.
- Following detection by the 3/2 valve cylinder A goes negative which will be speed controlled. As cylinder A goes negative the one way roller trip will be briefly activated to make the single acting cylinder B go positive and immediately negative. This cylinder will move the keg onto the line for TANK 2 using the suction pad. The speed control of the single acting cylinder must be able to be controlled on both the positive and negative stroke.
- The keg moves along the rollers (via gravity fall) to activate the micro-switch and make cylinder X go negative, emptying some of the contents of TANK 2 into the keg. Following detection by the 3/2 valve cylinder X will go positive to close the tank and restart the sequence.
- Emergency stops can be activated from either position to stop the air supply to all 5/2 valves. [15]

**(d)** On the pro forma provided (answer number **4(d)**) design and draw:

- A pneumatic system which uses the minimum number of components to enable cylinder N to be precisely controlled using micro-switches for the purposes of accurately loading the kegs via the suction pad. Micro-switches A and B must be connected in series to control one side of the cylinder. Micro-switches C and D must be connected in series to control the other side of the cylinder. Precision control will allow the operator to start or stop the movement of the piston at any stage as it goes positive or negative. [5]
- A pneumatic system which detects the arriving keg via the air bleed which in turn adds one to the counter before sending cylinder Z positive. The cylinder will automatically retract, without any form of physical activation, using the minimum number of components. [5]

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

Section C

Product Design

5   Car roof storage units like the one shown in **Fig. 5** below are designed and manufactured by companies in a range of sizes, shapes, styles and budgets.

Car roof
storage unit

Fig. 5

© Iurii Druzhynets/ iStock / Thinkstock
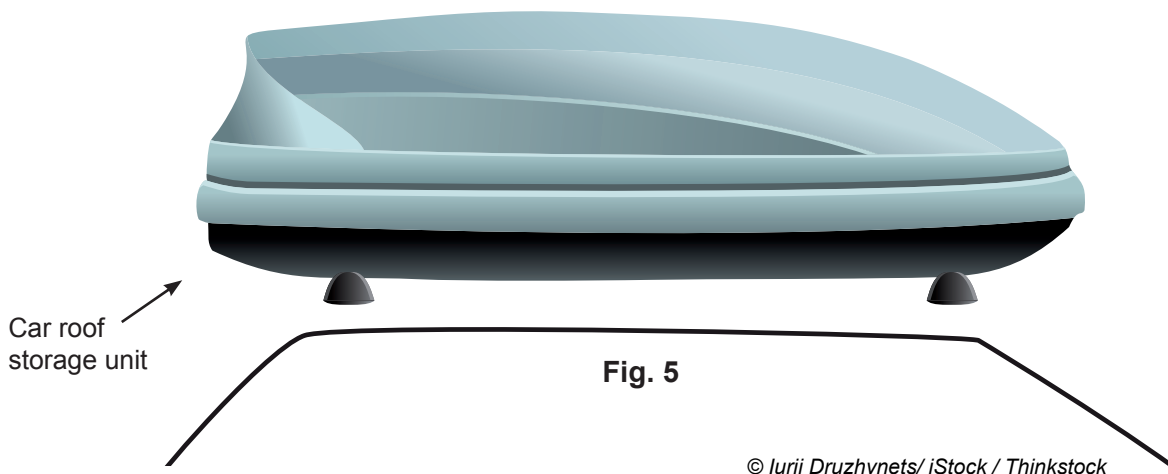
  (a) Market research plays an important role for any company designing and manufacturing these car roof storage units.

   (i) Explain the purpose of market research. [2]

   (ii) Explain why market research needs to be representative. [2]

  (b) Over the last number of years the range of car roof storage units that have appeared on the market may have been partly due to incremental product developments and partly due to Technology push.

   (i) Explain **two** main characteristics associated with incremental product developments which may have contributed to the design of products. [2]

   (ii) Explain **three** main characteristics associated with Technology push which may have contributed to the design of products. [3]

(c) When designing products companies need to be aware of international and regional differences which exist and the impact that these may have on their business.

With reference to **five** different specific product examples discuss how international and/or regional differences have influenced the design of each chosen example.   [5]

Quality of written communication   [4]

(d) Many models of car roof storage units have experienced the introduction, growth, maturity and decline stages of the product life cycle.

  (i) Describe **three** main differences between the main characteristics of introduction and the main characteristics of growth.   [3]

  (ii) Describe **three** main differences between the main characteristics of maturity and the main characteristics of decline.   [3]

(e) When promoting new models of car roof storage units it is important for companies to have a clear understanding of the limitations of the different promotional methods before formulating a strategy.

  (i) Explain **two** main advantages and **one** main disadvantage associated with the use of sales promotion as a means of promoting the product.   [3]

  (ii) Explain **two** main advantages and **one** main disadvantage associated with the use of trade fairs as a means of promoting the product compared to personal selling. [3]

(f) (i) With reference to **Fig. 5(f)(i)** below and using the blank A3 pro forma provided (answer number **5(f)(i)** and **(ii)**) design graphical information which could be printed on an instruction leaflet to convey to the person fitting and/or using the product the following information:

- The height of the garage door must be a minimum of 2.2 metres in order to provide clearance for the car with the fitted roof storage unit.
- The storage unit is designed with a maximum weight restriction of 60 kg with a recommendation of 50% of the weight in the middle, 25% on the front and the remaining 25% on the back rail.
- The storage unit should be centred on the length and width of the roof.   [5]
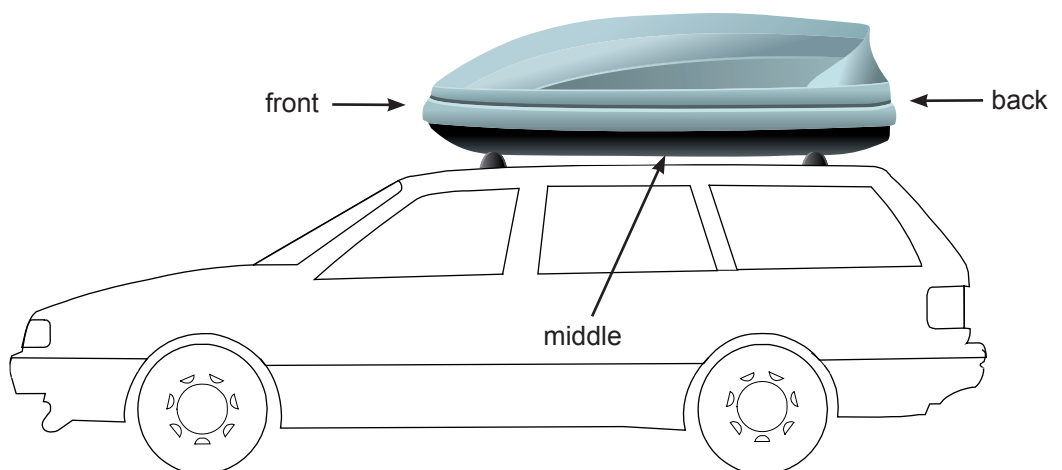
Fig. 5(f)(i)

(ii) The car roof storage unit shown in **Fig. 5(f)(ii)** is often used to carry a wide range of sporting, leisure and holiday making items. It is important that such items are firmly secured in position to prevent damage due to movement as a result of road conditions or driving styles.

Dimensions of car roof storage unit	
Length	1400 mm
Width	900 mm
Depth	400 mm

High Impact ABS housing (3 mm thickness)
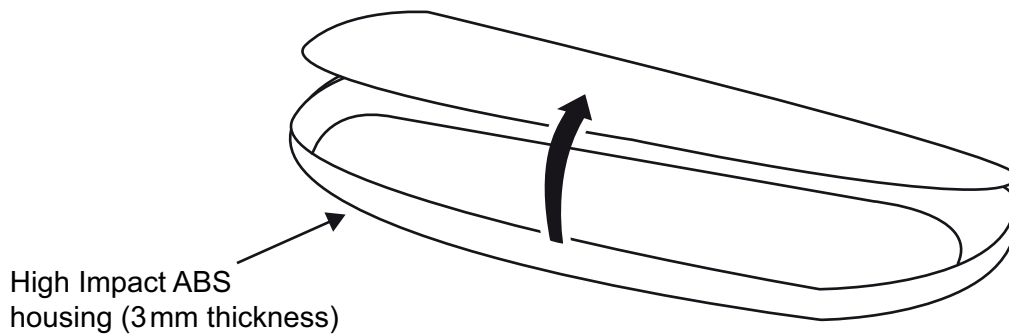
Fig. 5(f)(ii)

Using the blank A3 pro forma provided (answer number **5(f)(i)** and **(ii)**) produce a suitable design which will allow the user to quickly secure different sized items inside the storage unit to prevent damage during transit. Show how your design could be attached to the ABS housing of the storage unit. [5]

6 **Fig. 6** below shows a child's desk and chair which has been designed and manufactured by a company which focuses on domestic bedroom furniture.
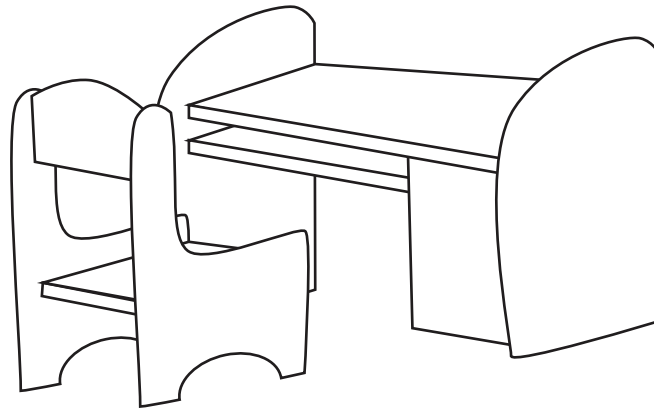
Fig. 6

Many companies are aware of the environmental issues relating to the design and manufacture of products. With the rising levels of greenhouse gas emissions and the impact this may be having on climate change many feel that the solution must come from reducing the causes of increased levels of emissions.

(a) Outline **two** main different causes of increased levels of greenhouse gas emissions which have resulted from human activity. [2]

(b) The work of marketing information systems (MIS) is to help businesses gain a better understanding of the market environment.

Briefly explain **two** main characteristics associated with each of the following tasks of the MIS:
• Product research.
• Distribution research. [4]

(c) When developing a market strategy to guide the direction of the company producing domestic bedroom furniture, decisions were taken by management to consider the views of the market development and product development teams.

(i) Briefly explain what is involved in market development and give **one** main reason why the management of this company might consider the team's views as high risk. [2]

(ii) Briefly explain what is involved in product development and give **one** main reason why the management of this company may look positively on the team's views. [2]

(d) When determining a suitable price for the child's desk and chair the company considered using either the perceived value pricing method or the cost-plus pricing method.

    (i) Explain what is meant by the perceived value pricing method. [2]

    (ii) Briefly outline **two** main problems associated with the cost-plus pricing method which may influence the decision of the company not to use this method. [2]

(e) As the company continually strives for improvement the role of a quality assurance process is very important.

    (i) Explain **one** main quality assurance process that could be used by the company. [2]

    (ii) Explain how this could benefit the company on its journey of improvement. [2]

(f) Designers try to reduce material use in products in an attempt to minimise costs whilst maintaining the functional and performance characteristics.

Select **two** different examples of products and explain how the designer has specifically managed to reduce material use. [4]

(g) Many products incorporate social and economic factors in their design.

    (i) Choose **one** example of a product and describe how it incorporates social factors in its design. [2]

    (ii) Using a different example, describe how another product has incorporated economic factors in its design. [2]

(h) Dyson is a designer who has revitalised many different products.

Explain **two** main characteristics associated with the influence of Dyson. [4]

(i) **Fig. 6(i)(i)** below shows a child's desk that was designed and manufactured by a student.
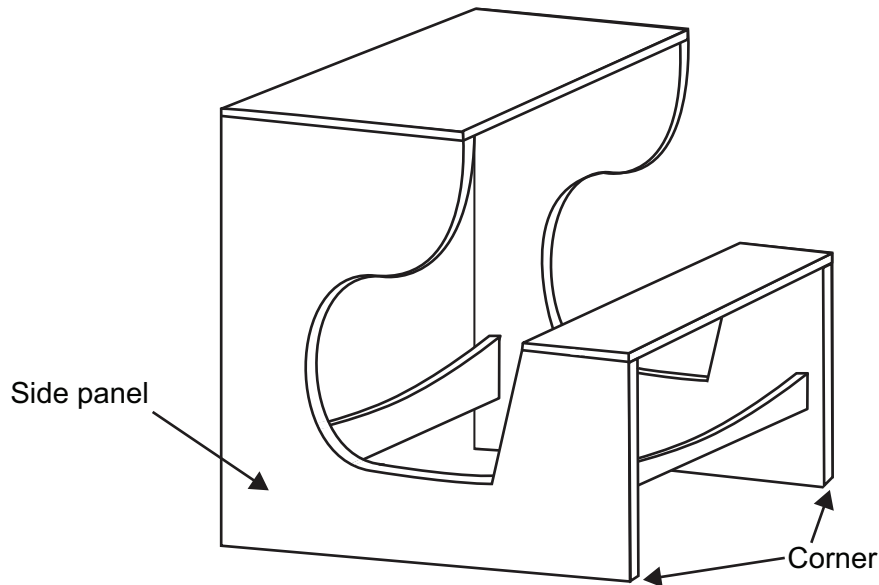
Fig. 6(i)(i)

(i) During testing of the desk shown in **Fig. 6(i)(i)** it was found that repeated movement caused the corner of the side panels to produce scrapes and markings on tiled and wooden floors. In addition the desk does not remain stable on uneven surfaces.

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

Annotated sketches of a low cost floor protector that can be quickly and securely fitted to the corners of the desk and will enable the desk to remain stable on uneven surfaces. [5]

(ii) In **Fig. 6(i)(ii)** below the side panel is joined to the work surface by simply drilling and securing two wood screws. During testing of the product concerns were expressed that this did not provide sufficient support for the work surface and it lacked the aesthetic finesse required by this product.

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

Annotated sketches of a redesign to secure the side panel to the work surface to provide:

• Low cost adequate support with aesthetic appeal with minimal use of materials. [3]

Explain how your redesign would be appropriate for batch production. [2]
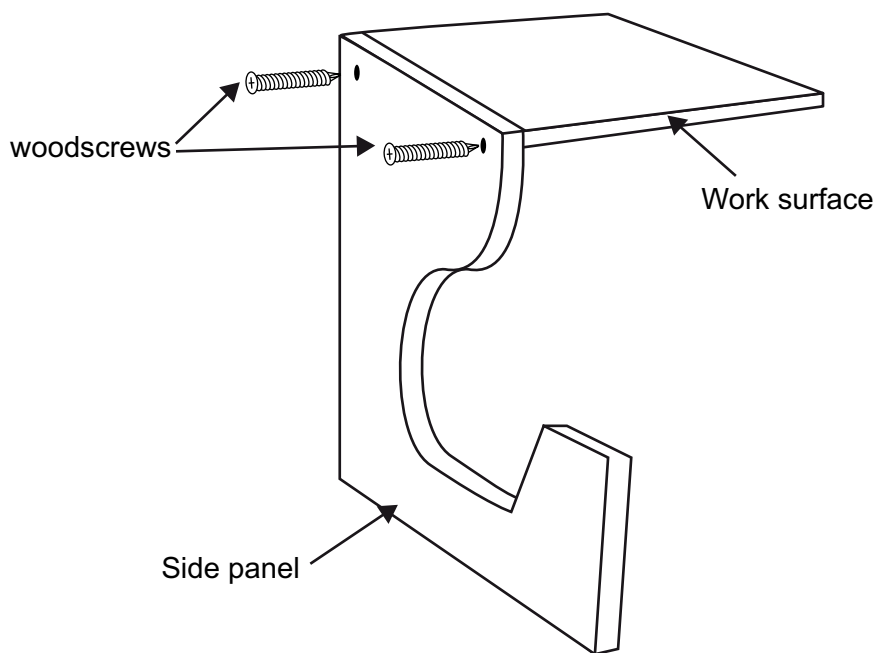
Fig. 6(i)(ii)

_____

THIS IS THE END OF THE QUESTION PAPER

_____

| 7 segment decoder | 7 segment decoder |

seven segment displays
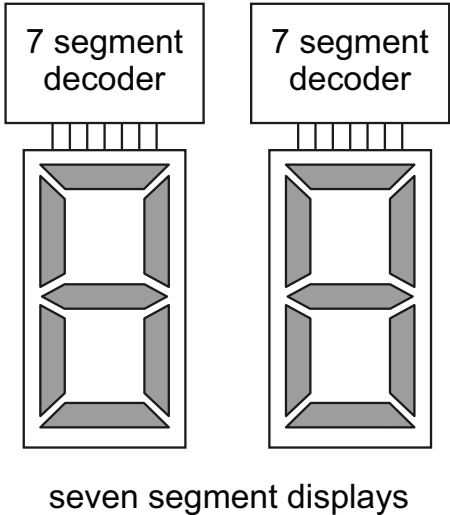
Pro forma answer page
(answer number 1(e))

**Pro forma answer page
(answer number 2(e))**

TANK 1

KEG

A

W

TANK 2

X

LOADING

BAY CHUTE

**KEG MOVES ALONG
THE ROLLERS (VIA
GRAVITY FALL)**
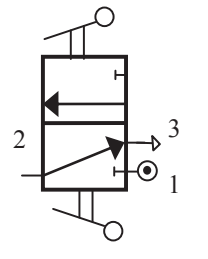
SUCTION
PAD

B

GROUP CHANGE
OVER VALVE
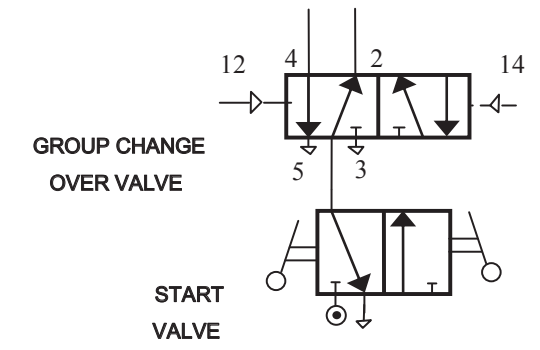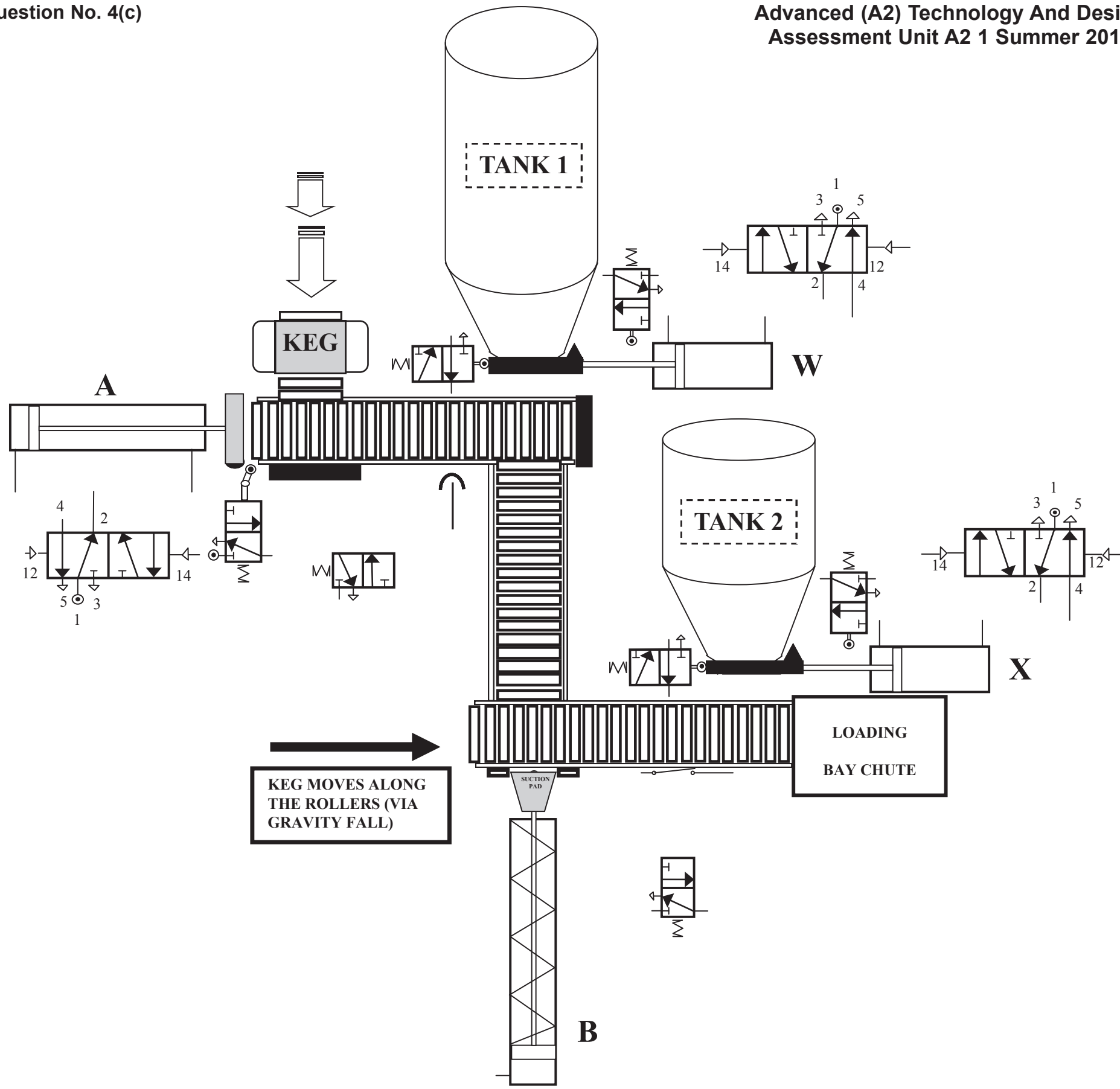
START
VALVE

**NOTE:
CYLINDERS X AND W ARE DRAWN
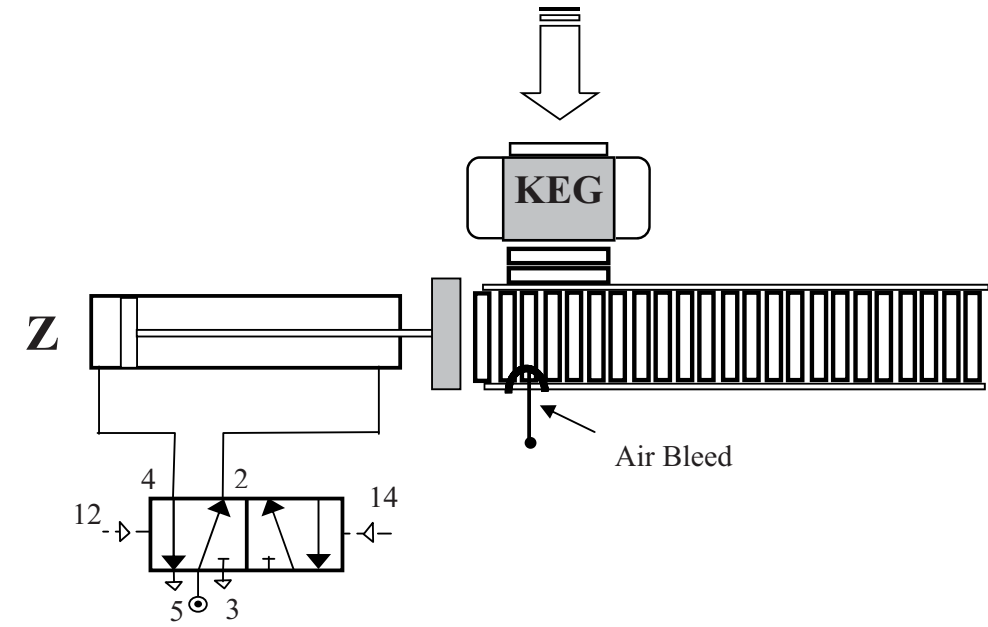IN THE POSITIVE STROKE AT THE
START OF THE SEQUENCE**

Emergency Stop
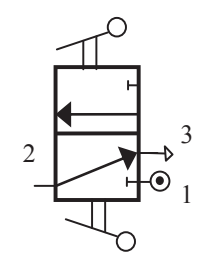
Emergency Stop

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

**Micro-switch
A**

**Micro-switch
B**

+12V

N

SUCTION
PAD

KEG

Z

Air Bleed

4   2   14

12

5   3

**Micro-switch
C**

**Micro-switch
D**

+12V

| 1 | 2 | 3 | 4 |

Counter
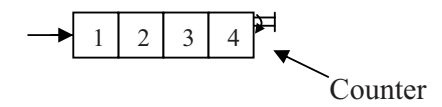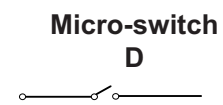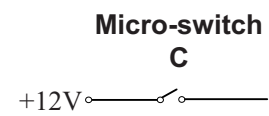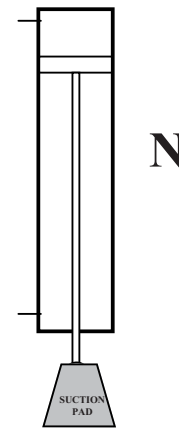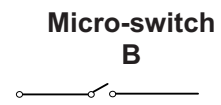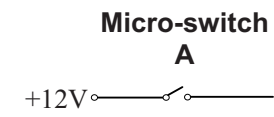
**Pro forma answer page
(answer number 4(d))**

9289.02

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

Pro forma answer page
(answer number 6(i)(i) and (ii))