MANUFACTURING ENGINEERING TRIPOS PART II

Wednesday 21 April 2004 9 to 12

PAPER 1

Answer not more than ***four*** *questions. Answer* **each** *question in a separate script paper booklet.*

All questions carry the same number of marks.

The **approximate** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Attachments:
Special data sheet (1 sheet)

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 (a) Metal matrix composite (MMC) and carbon-fibre reinforced plastic (CFRP) are both materials with properties which are potentially valuable for the automotive industry. Neither has achieved mass-market penetration, however. With reference to aluminium-matrix SiC particle-reinforced MMCs and long-fibre CFRP:

(i) Give examples of applications within the automotive sector for which they might be suitable, indicating their advantages over conventional materials; [20%]

(ii) Discuss the barriers to their introduction to this sector. [30%]

(iii) What additional factors would be important in considering the use of these two materials in the aerospace industry? What sort of damage should routine maintenance inspections seek? [25%]

(b) An automotive company operating in the low-volume sports car market intends to launch its new hi-fi audio system in October 2004, and has formed a partnership with a small UK-based company which will provide the loudspeakers. These are assembled from parts sourced from a number of companies in UK and Asia. Prototyping was completed in October 2003 and production of the first 1,000 loudspeakers begun. Unfortunately, 70% of the first batch showed unacceptably erratic performance when tested in April 2004.

You are advising the company which supplies the loudspeakers. Discuss the technical and business steps you would take to attempt to solve the problem. [25%]

2 (a) In the context of the electronics industry, explain what is meant by:

(i) a surface mounted component;
(ii) a ball grid array;
(iii) reflow soldering;
(iv) ion implantation during the manufacture of an integrated circuit;
(v) leakage in a microprocessor. [40%]

(b) Discuss the technical and business aspects of the two developments below and how they may affect electronics products, processes and manufacturers. Contrast the implications for small versus large firms.

(i) lead-free soldering; [40%]
(ii) polymer-based semiconductors. [20%]

3 The automation of assembly operations is a complex undertaking, and may require many months of project effort before it is successfully accomplished.

(a) Briefly describe the main stages of an automation project. [25%]

(b) Discuss the purpose of a functional specification, explaining why it is important. [25%]

(c) Discuss the factors you would take into account when deciding whether to set up an assembly system to produce mobile phones either:

(i) with manual labour;
(ii) with robot cells;
(iii) with 'hard' automation. [40%]

(d) In the light of your answer to (c), comment on how current mobile phone assembly systems are likely to be configured. [10%]

4 A chemical factory manufactures a range of adhesives in a series of batch reactors. The products are either water-based or solvent-based. Product is packed into various containers (cans, squeezable tubes, etc) on several filling machines. Reactors, pipe-work and packing machinery have to be cleaned when changing from one product to another. Packing machines can accommodate different sizes of container, but require adjustment and tooling changes to enable this. Changes to labelling are relatively straightforward, and the business supplies both retail and industrial customers. The factory is working two shifts five days a week with a Saturday "maintenance" dayshift and there is little, if any, spare capacity in the operation.

(a) (i) Explain the meaning of the following performance measures in use in the factory: On Time in Full (OTIF); Overall Equipment Effectiveness (OEE); Schedule Adherence.

(ii) How, if at all, do each of these measures reflect the customer service and internal efficiency of the plant?

(iii) What is the benefit of benchmarking performance with other plants and industries? [35%]

(b) There is increasing demand for variety in product and packaging and for reduced lead-times. Performance measurement and benchmarking has produced the data in Figs. 1 and 2. In Fig. 2, the "box and whiskers" elements refer to internal benchmarking data (refer to the key provided) while the vertical axis reflects external best practice. Note, also, that Grade change time refers to time taken to change between product grades.

(i) Estimate OEE for the plant.

(ii) Indicate which performance measures suggest opportunity for improvement.

(iii) Which performance measures would you focus on to help manage the increasing demand for variety? Explain why. [30%]

(cont.)

Measure	% of Ideal
Production Rate	96.0
Quality Rate (yield)	97.8
Scheduled Downtime	9.9
Unscheduled Downtime	4.1

Fig. 1: Plant Performance Measures as a Percentage of Ideal Performance

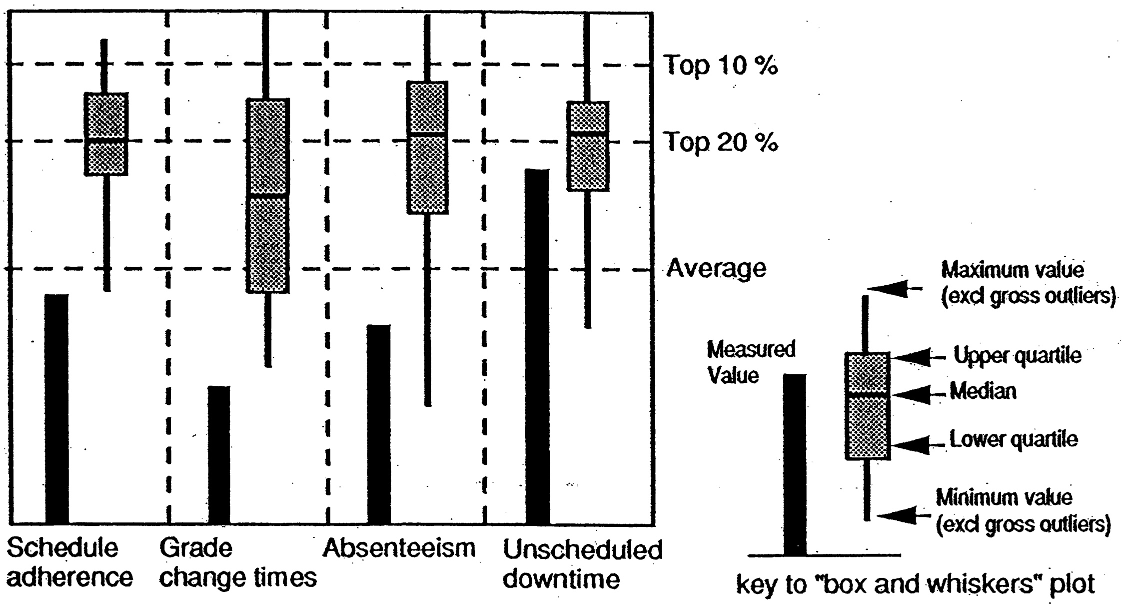


Fig. 2: Plant Performance Measures against Best Practice

(c) The company operating this plant competes by offering shorter lead times and higher product variety than other firms in its market. This allows them to charge a price premium. Success means that volumes are rising, however manufacturing costs are escalating. This is due to increasing overtime and temporary staff to cope with the complexity in planning and production caused by this policy. What approach would you recommend to deliver improvement? Mention key elements of the programme and include relevant tools you would use. [35%]

5 (a) Describe three ways in which bottlenecks can be created in a production process. [10%]

(b) Fig. 3 shows a three stage production process:

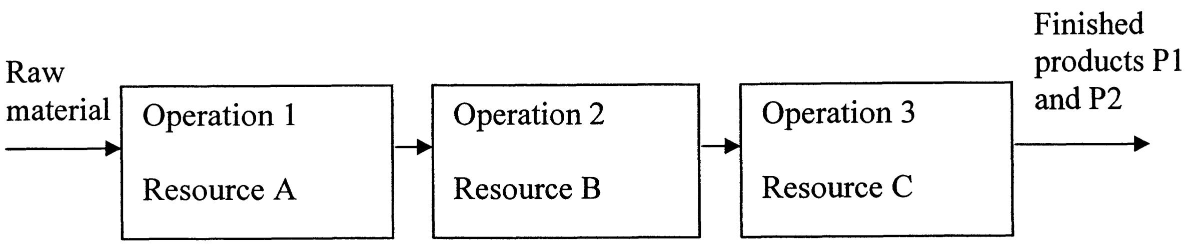


Fig. 3

The process converts one unit of raw material into one unit of finished product, either P1 or P2. Each of the two products must pass through all of the three operations: 1; 2; and 3. Each operation uses a single dedicated resource: A; B; and C respectively.

Table 1 below shows, for each resource, the set up times for products P1 and P2, and the time required to make one of each of the products P1 and P2.

	Set up time P1 (mins)	Set up time P2 (mins)	Make time/unit P1 (mins)	Make time/unit P2 (mins)
Resource A	10	30	5	1
Resource B	20	5	5	5
Resource C	1	3	10	10

Table 1

(cont.)

The production process is set up to make P1 followed by P2, in equal batch sizes. What is the bottleneck resource when the batch size is 2 and when the batch size is 20? In each case, what causes the bottleneck? [25%]

(c) In practice, resource B suffers numerous break-downs, so it is effectively only 50% efficient. Does this affect the location of the bottleneck for batch sizes of 2 or 20? Give reasons for your conclusions. [25%]

(d) Using a policy based on tackling the causes of bottlenecks, what action might you take to improve the throughput and delivery reliability of the production process? Indicate how you would prioritise these actions. [40%]

6 (a) Briefly discuss the advantages and disadvantages of using pneumatics in automation. [20%]

(b) A clamping operation involves closing and opening clamps in the following sequence: Close clamp A; Close clamp B; Open clamp A; Open clamp B. The clamping cycle is started by pressing a manual push button.

The clamps are closed and opened by double-acting pneumatic cylinders. To avoid impact damage the speed of closing of the clamps must be adjustable. Clamp opening should be rapid.

Design a pneumatic circuit to automate this operation. [70%]

(c) It is proposed to change the sequence to: Close clamp A; Close clamp B; Open clamp B; Open clamp A.

Explain the major circuit design problem resulting from this change and state the type of circuit design that will be needed to allow this sequence to be automated. (You are not expected to design the circuit.) [10%]

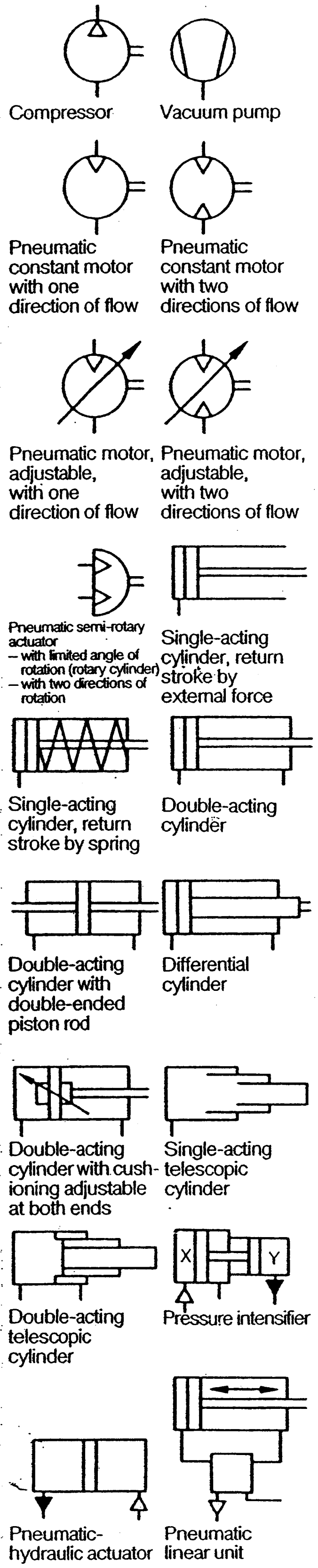
You may make use of the pneumatic and logic symbols data sheets provided.

END OF PAPER

Pneumatics and Logic Symbols

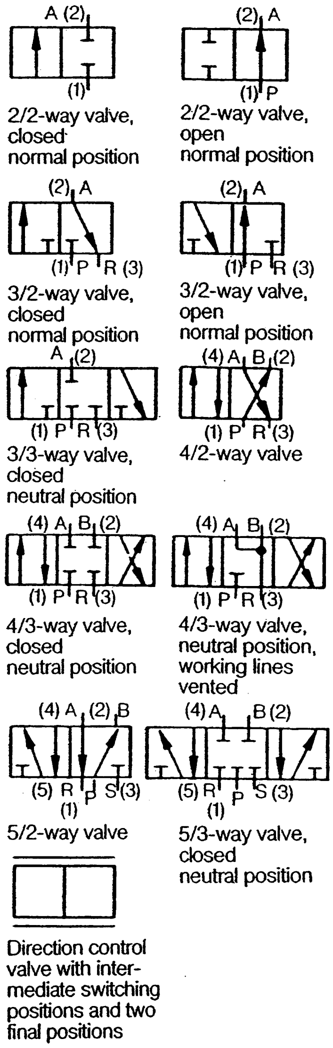
to ISO 1219

Energy Conversion

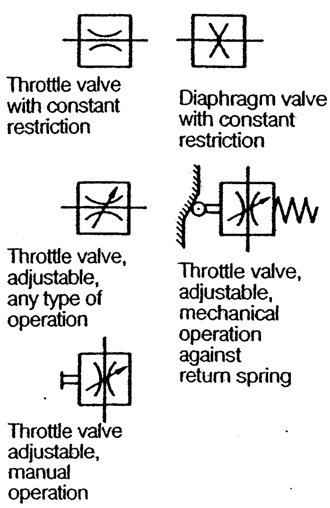


Valves

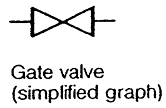
Directional Control Valves



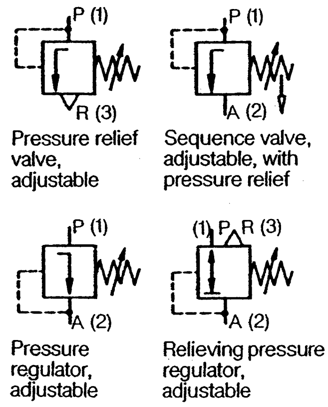
Flow Control Valves



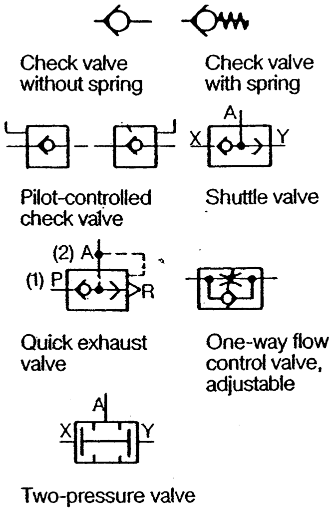
Gate Valve



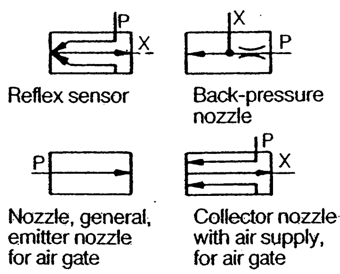
Pressure Control Valves



Non-Return Valves



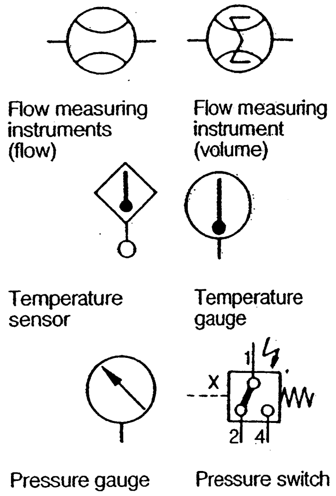
Special Symbols*



* = not standardized, proposal

Other Symbols

Other Devices

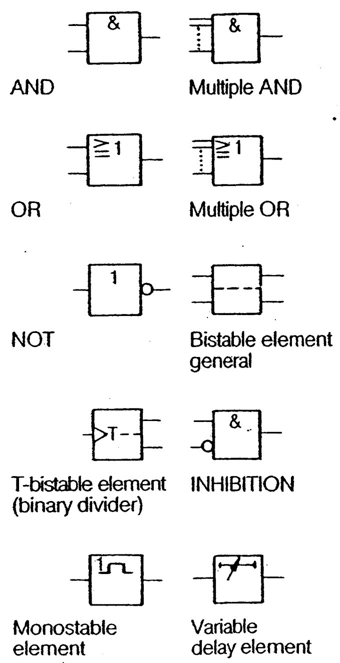


ISO STANDARD 5599/II

Designation of Connections

A, B, C (2, 4, 6)	working lines
P (1)	compressed air connection
R, S, T (3, 5, 7)	drain, exhaust points
L	leakage fluid
Z, Y, X (12, 14, 16)	control lines

Logic Symbols



Pneumatics and Logic Symbols

to ISO 1219

Energy Transmission

- Working line
- Flexible line
- Pressure source
- Electric line
- Control line
- Exhaust line
- Line connection (rigid)
- Line cross-over
- Exhaust point
- Silencer
- Drain without pipe connection
- Drain with pipe connection
- Air connection point, closed
- Air connection point with connected line
- Quick release coupling, coupled
- Quick release coupling with mechanically opened nonreturn valves, coupled
- Quick release coupling, uncoupled, line open
- Quick release coupling, uncoupled, line closed
- Rotary connection with one path
- Rotary connection, e.g. with three paths
- Pneumatic capacitor
- Filter
- Water trap, manual
- Water trap with automatic drain
- Filter with water trap
- Filter with water trap, automatic
- Cooler
- Cooler
- Dryer
- Lubricator
- Service unit (simplified graph)

Control Methods

Mechanical Components

- Detent
- Over-centre device
- Shaft rotational movement in one direction
- Shaft rotational movement in two directions
- Locking device (*control method for releasing the locking device)
- Hinge joint with extended lever
- Hinge joint, simple
- Hinge with fixed pivot

Pressure Controls

- Direct by application of pressure
- Pressure centred
- Differential pressure actuation
- Spring centred
- Indirect by application of pressure

Combined Controls

- By solenoid and pilot valve
- By solenoid or pilot valve
- By solenoid or manual operation with return spring
- General, *explanatory symbol

Manual Controls

- General
- Button
- Lever
- Pedal

Mechanical Controls

- Plunger
- Spring
- Roller
- Roller with idle return

Electrical Controls

- Solenoid with one effective winding
- Solenoid, e.g. with two windings acting in opposition
- Electric motor with continuous rotary motion
- Electric stepping motor

Special Controls

- By application of pressure through pressurized amplifier*
- By application of pressure, type of control produces alternating behaviour*

* = not standardized, proposal

- Mechanical return
- Actuated in starting position

050 170 GB