MANUFACTURING ENGINEERING TRIPOS PART II

Wednesday 25 April 2007 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.*

There are no attachments.

CRIB

STATIONERY REQUIREMENTS	SPECIAL REQUIREMENTS
8 Page Script Paper Booklet x 4	*Engineering Data Book*
Rough Work Pad	*CUED approved calculator allowed*

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

Question1

This question was set by Mr David Probert and relates to information provided in the MET II, Assembly and Electronics Module.

Answer

(a) Embedding software. Given that the decision has been made to include software in the new product, we start from the assumption that there is a market justification for this, and no extra marks are to be given for discussion of market considerations(K ano model etc). The main issues to be considered then become those of the software development itself and the suitability of the development team to undertake this task.

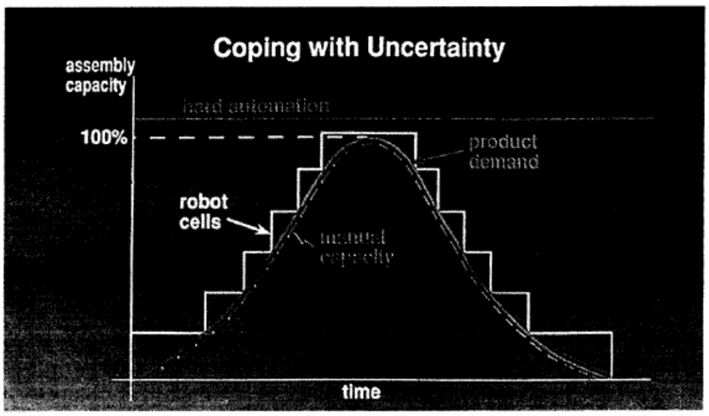
Good candidates will review the characteristics that make software different from hardware(changeability, complexity, invisibility), and all candidates should identify that different skills and experience are required compared to hardware development. The complexity of the software development will depend on the nature of the finished software itself - whether it is real time or non-real time, and whether it is safety critical or not. In this case it should be a relatively simple piece of software - not by necessity real time and not safety critical. However there are many factors to consider before deciding whether to carry out this development in –house or to work with a sub-contractor. Good candidates will make a full discussion of all of these. An initial assessment of whether to go outside the firm depends on:- Know-how: do we have the knowledge to carry out the development? Capacity: do we have the resources to carry it out? Cost: is it cheaper to do it inside rather outside the firm? Core competence are we risking giving away sensitive product or process knowledge buy working with a contractor? Flexibility: will developing this skill in house provide the ability to undertake future tasks with advantage? If it appears that external sourcing of the software development is a good possibility, a more thorough analysis can be undertaken by means of applying the sourcing checklist that was covered in the module. This covers the following topics (see enclosure for more detail):

Business interest: is it really in our company's interest to do this task externally?
Task suitability: how suitable is this task for performing externally?
Supplier suitability: how suitable is the proposed software supplier?
Collaborative arrangements: are the necessary arrangements in place?
Some exceptional candidates may also consider the nature of the development process, the impact on manufacturing and testing of the product, and additional credit should be given for this.

(b) Product design. Since this product appears to be an evolution from Previous hardware only designs, it would be appropriate to consider the application of DfX and VA/VE techniques. DfX covers design for assembly, manufacture, whole life etc, although the prime consideration is likely to be assembly. This approach applies mainly to new products, where assembly methods are not yet decided. The issues of parts minimisation, reduction of different materials, and relative movement of parts should all be considered together with the designing out of wires and cables. VA/VE (value analysis/value engineering) can be applied to both current and future designs, in order to increase the ratio of function/cost for the customer. Good candidates will review the VA/VE methodology and discuss how it applies to the shaver design (definition of value as function/cost, identify components/subsystems and estimate costs, list functions, evaluate functional cost by means of value matrix, evaluate functional importance by means of the emphasis curve, and investigate improvement - how to improve value).

(c) Product assembly. Considerations of product assembly method and location are linked to many factors. Candidates may refer to the Puttick grid (volume vs variety) that was covered in lectures, and decide that this is likely to be a high volume low variety product, and as such a candidate for some form of automated assembly. The criteria which determine the suitability of an assembly method (automated or manual) are a combination of flexibility, reliability, quality, speed, capital investment, running cost, volume growth and product life, and hazards.

Candidates should discuss these in relation to hard, soft (robotic) and manual assembly methods. Parts quality and supply, and testing of the final product also need
to be considered in the overall economic justification that does not ignore the people factors. Good candidates may draw the graph that shows the comparative advantage of robotic assembly over hard automation if volumes are uncertain: The location of assembly is again a matter of cost, but also logistics and market geography. It may be cheaper to assemble in the far East either manually or automatically),but logistics costs and risks need to be taken into consideration.



END OF ANSWER

Question 2

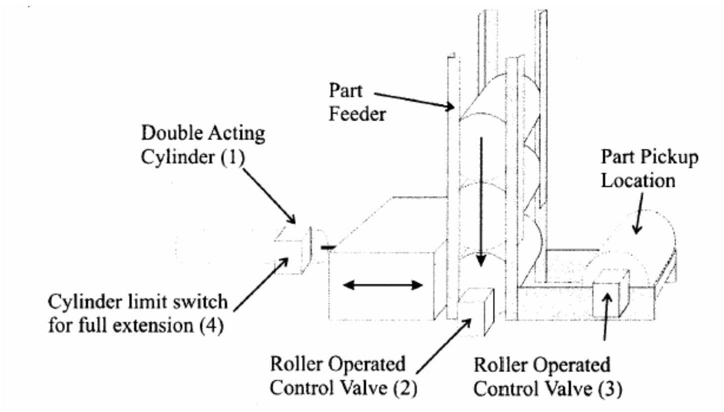
This question was set by Dr Ken Platts and relates to material delivered in the Robot module.

a) When expressing advantages and disadvantages these must be related to other potential working media; the most obvious are electrics and hydraulics.

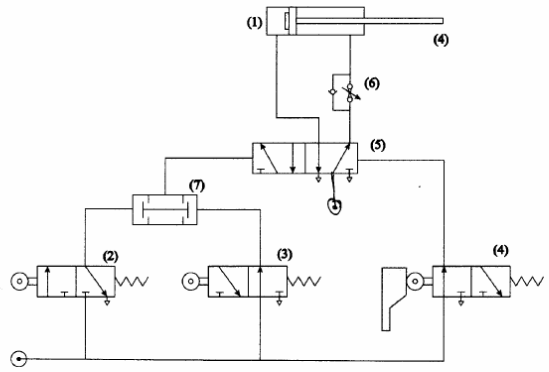
Advantages include:
Adjustable - speeds and forces are variable over huge ranges. Speed - fast working medium - cf hydraulics Cleanliness - very clean if un-lubricated air, important in eg. Food industry. Explosion proof and also minimal risk of fire - cf electrics, important in eg chemical industry. Temperature - relatively insensitive to temp variations. Overload safe - tools and components can be overloaded to point of stopping without damage.

Disadvantages include:
Need for good air preparation - air needs to be dry and dirt free. Compressible - therefore not easy to achieve uniform, constant movements. Noise level - high pressure air exhausting is noisy - can be mainly solved with silencers etc. on exhaust ports. Costs - relatively expensive means of conveying power cf electrics. Force limits cf hydraulics.

b)



2b i) continued..



(1) Double acting cylinder, cushioned
(2&3) Roller operated control valves 3/2 way
(4) Limit switch for detecting full extension
(5) 5/2 Way valve
(6) Flow control valve on output side to control piston transfer speed
(7) Two pressure valve 'AND' function

NOTE: Other circuits are also possible.

2b ii)

The solution is to add an escapement at the bottom of the part feeder. This would control the flow of products in the part feeder and only allow one product to drop into the bottom eject location. The part in the eject position could then be ejected into the pick up location ensuring that all other products are held securely in the feeder. Once the eject process has finished and the cylinder has retracted back to its normal position another product could be released by the escapement to drop into the eject position. (The cycle continues)

Mechanical modifications.
The system would be modified by adding another pneumatic double acting cylinder and arm that would insert itself between the bottom product and the second from bottom product. When this arm extends it would restrain the stack of products in the feeder from dropping. A limit switch for full extension would have to be used on this cylinder to ensure feed back on it operation id obtained.

Pneumatic modifications.
The escapement gate should only be released when control valve 2 is in 'free' state and (to be safe) double acting eject cylinder has returned to retract position. This will require the addition of a further limit switch and another 'AND' gate. The circuit complexity is substantially increased.

END OF ANSWER

Question 3

This question was set by Dr Claire Barlow and relates to information from the MET II components module.

a) Balance sheet with contributions from the three ‘accounting’ streams of Economic, Environmental, Social performance. Measurement and weighting of these different aspects may not be straightforward, but there is an attempt to quantify and compare. The economic aspect is of course the traditional measure of corporate success, and straightforward to assess. Environmental performance can be measured in various ways, though none unambiguously or uncontroversially (e.g. emissions, energy consumption, amount of landfill, use of hazardous substances). Even more difficult is the social aspect, where examples include contribution to the local community, care of the workforce, existence of family-friendly employment policies.

Tensions arise between all the aspects, e.g.:

Pressure from shareholders to maximise profits means there will be Continuous cost-cutting. This can be good for sustainability, e.g. If waste reduction is targeted, then there will be -

Increased resource and material usage efficiency
Reduction in consumption of non-value adding materials - e.g. packaging
Improved quality control e.g. “Right first time” to minimise off-specification product: cuts down scrapped products, re-work, returned goods etc

However, more often continuous cost-cutting is bad for sustainability, e.g. Reduced labour costs: cut in number of employees (so bad for the social bottom line) Growth: More product, bigger sales (so more goods created – bad for the environment) Cheap products rather than quality goods (so more rapidly become waste; bad for environment). Focus on short-term gain, rather than long-term goals The business case for sustainability is generally weak - unless it is a source of competitive innovation, when it can lead to tremendous market strength. Otherwise, the business case can be modified by tax, e.g.

Landfill tax
Transport - air-fuel
EU - end of life
‘Unitax’ - tax energy not income/profit

b)

(i) Post-consumer waste is typically mixed and contaminated. Industrial waste is generally closer to being a single material, and if it is contaminated then the nature of the contaminant is generally well-defined. The volumes of material are often relatively high.

Sorting of waste is technically difficult and/or costly. It can, for example, be done economically and to a good degree of accuracy by hand where labour costs are low, e.g. China. But elsewhere, automated or semi-automated processes are required, and these are expensive and do not deliver the required quality control. If the materials are joined to other materials (as it often is in a product, e.g. a PCB, a car) then physical separation may be difficult, expensive, or technically impossible.

Contamination (e.g. from foods) is problematic, mainly for economic reasons, but sometimes technical. Cost margins for low-value materials such as polymers are slender, and there is no slack to allow for thorough washing processes. For materials such as metals (where high-temperature processing is typically used, including some kind of a purification stage), the problem is reduced. Industrial waste is more likely to be uncontaminated, or to be contaminated with something which can be removed by some well-defined and targeted process. The better quality control of the waste stream means that prices commanded for the scrap are normally higher.

One of the main post-consumer waste problems is social. Householders put forward only a small fraction of their waste for recycling, even when facilities and mechanisms are in place (but logistics are a real problem for post-consumer waste: collection and storage). Industrially, the same is often true, and here the ostensible reason will often be economic, although the underlying cause often has social elements (lack of environmental commitment in the company). There are logistical elements too: waste needs to be stored until volumes are great enough that it is economically viable for it to be collected. This adds costs.

(ii) Paper is significantly degraded by recycling (reduction in fibre length and hence strength). Conventional recycling uses a lot of resources, especially water. There are also contributions from transport. However, the process of making paper is even more resource-intensive. On balance, recycling of office paper is viable even on economic grounds; recycling of lower-grade paper may be somewhat environmentally attractive but economically neutral or negative. If the transport element is removed (e.g. by localised recycling) the equations balance better; the situation is improved still further if the recycling process can be 'short-circuited', so that it is not necessary to return all the way to the pulp stage.

(c) Towards zero waste: Waste output from one company used as the raw material input for another. Original networks in Pittsburgh (USA), and in Kalundborg (Denmark) NISP (National Industrial Symbiosis Programme) was founded in 2003 UK as the first National IS network in the world. "Brokers" exchanges of information, expertise and materials between companies and organisations. Immediate savings for participants (landfill avoidance; savings in virgin material costs; revenue from waste); many opportunities for new business generation.

Industrial Symbiosis in the Kalundborg district of Denmark. A co-operative network between five industrial enterprises and the municipality of Kalundborg: Asnæs Power Station, GYPROC (plasterboard manufacturer), Novo Nordisk/Novozymes (pharmaceutical & biotechnology), A/S Bioteknisk Jordrens (soil remediating), STATOIL (oil refinery). Companies trade by-products: the waste of each is a valuable raw material to one or more of the others. The result is a reduction of both resource consumption and environmental impacts. "The six business partners also gain financially from the co-operation because all contracts within the symbiosis are based on sound commercial principles."

Advantages of symbiosis
Trading their by-products offers participants:

* Reuse of by-products. The by-product of one enterprise becomes an important raw material for another.
* Reduced consumption of resources, e.g. water, coal, oil, gypsum, fertiliser, etc.
* Reduced environmental impact in the form of smaller emissions of CO_2 and SO_2, smaller discharge of waste water and less pollution of ground and surface water
* Better utilisation of energy resources. Waste gases are used in the energy production process.
* Benefits for the local community: centralised heat production; less pollution.

Criteria for symbiosis:
1. The enterprises must function together. Need the right composition of enterprises in an area. Waste products from one enterprise must fit the raw material need of other enterprises. Diversity in the local industrial structure is therefore a necessary precondition for implementation of industrial symbiosis.

2. The enterprises must be situated near each other. Long pipelines are costly structures to install; minimising length also minimises energy losses. Distance is most important when energy is being exchanged; less important in the case of other by-products.

3. Cultural similarity, common goals and openness (trust) between the enterprises Kalundborg is small and comparatively isolated. The decision makers working there all know each other and have developed a relationship characterised by openness, communication and mutual trust.

END OF ANSWER

Question 4

This question was set by Dr Claire Barlow and relates to information from the MET II components module. This is a deliberately open-ended “master’s-style- question which is thought to be demanding and appropriate at M.Eng level

(a) Materials to focus on would be aluminium-matrix composites containing silicon carbide particles or short fibres, and polymer-matrix composites reinforced with continuous or chopped carbon fibres. A good answer will look at: Material properties, and their relationships to conventional materials used for comparable applications; Material fabrication and availability, how articles can be manufactured from the material, end-of-life issues; The extent to which the use of these materials requires displacing conventional materials, and whether this is likely to present problems; Costs at every stage.

MMCs: Expensive, 20-50% enhanced strength, 50% increased elastic modulus, enhanced wear resistance, better fatigue resistance, reduced toughness. Limited availability, but no problem with ramping up production if required. Novel processing methods required for making material, so only produced by a small number of companies. Manufacturing uses conventional processes: forging, machining etc., though high hardness causes increased tool wear. Joining is problematic: e.g. glue joints used for bikes. Real limiting factor is cost, which for most applications is excessive for the mechanical property enhancement. Applications where property-weight ratios are crucial. There are niche applications: cycle tubing for top-end bikes; now entering the mass-market automotive market with gear selector forks and brake callipers; Airbus 380 wheels. Vicious circle arguments: Prohibitive costs will limit further penetration, unless there were a high-volume application which drove material costs down dramatically. Recyclability: mixing with conventional aluminium alloys will require extra filtering to remove the particulate, but not insuperable. The possibility of collecting MMCS together for recycling would be logistically impracticable.

CFRP: Carbon fibre, continuous or short, in epoxy resin matrix (rarely anything else). Expensive. Enhanced elastic modulus in particular; strength also important. Low density. Compete against aluminium, steel, and to a lesser extent GFRP. Material availability low: production is being ramped up but not fast enough; production of fibre is rate-limiting step. Manufacturing processes for articles: Very problematic, since completely different from metals, and also slow and ‘craft-based’. Displacive technologies encounter huge resistance. Joining a major difficulty. Damage detection problematic. Current uses: top-of-the-range automotive, aero; also bikes. Cost is the major limiting factor, and again this is a vicious-circle argument.

(b) A complex trouble-shooting problem, which may implicate external suppliers, aspects of transport and logistics, materials and fabrication. Some likely issues: Polymer bottles and caps: Was leakage between bottle and cap? Either may be faulty (change in polymer specification; change in process detail, e.g. speeding up production rate; tooling may be getting worn so parts are off-tolerance). Check on specification; check with supplier for any changes whatsoever, even ones which they don't expect to cause any problems. Go and see them rather than relying on what they say. Likely to be different manufacturers for bottles and caps. Were bottles and caps intact, or were there splits in either? If so: manufacturing issue, or possibly environmental stress cracking, perhaps from something in the packaging, or present during shipping. Is the chemical itself the same as usual, or has there been a change to that? How are caps put on bottles? Has it changed in any way?

Transport and logistics: How do the bottles travel? Air or sea? Either way, there will also be road transport both at UK and US ends. Plenty of scope for: Sitting about in temperature extremes, which could cause differential thermal expansion/contraction; Rough handling; dropping of package. Find out details of the package's journey; was anything different from usual?

Immediate steps: PR. Issue statement that problem is being investigated. Put someone in charge of investigation. Consider delaying next shipment; otherwise, enclose each bottle in a sealed bag to contain any leaks (which might become standard practice). Check internal procedures in company, looking for changes or irregularities. Interview everyone involved at any stage with the shipment. Look at everything sourced from external suppliers, e.g. bottles, caps, shipment packaging: visual inspection; were orders correct and as usual?

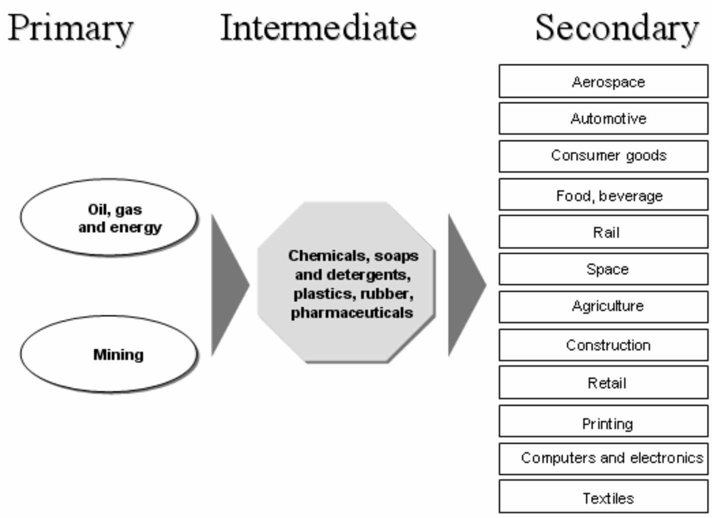
END OF ANSWER

Question 5

This question was set by Dr. Bill O'Neill and relates to information delivered in the MET II Process Module.

a) Process manufacturing is used to describe those operations that deal with continuous media where reactions or a change in state occurs. Examples being: chemical reactions; boiling, condensing, evaporating, melting, solidifying, cooking, fermenting. The scope of process manufacturing includes Oil and gas, chemicals, plastics, utilities, metals, building materials and supplies, pharmaceuticals, bio products, personal care and food and drink. Process manufacturing is very important to the UK economy as it contributes significantly in terms of production volume and value added. An example is the pharmaceutical industry. Pharmaceutical is the biggest investor in R&D in the UK – 25% of the total or 10% of world R&D expenditure and has generated 6 out of the world's 25 best selling medicines. The production operations in the process sector can deliver huge volumes. For example a power station can burn tons of coal per minute, paint plants can produce millions of litres per year, or a naphtha cracker can produce up to 0.5 million tons of ethylene or propylene per year. Chemical operations in the UK deliver around 11% of UK manufacturing output which equates to an export provision of around £25 billion per annum.

b) Primary products refer to the provision of oil, gas, coal etc and lead to the finished products through intermediates such as chemicals, soaps and detergents as illustrated below. Secondary products refer to food and drink, household, pharmaceuticals, personal care products etc. These are often termed Fast Moving Consumer Goods (FMCG) and account for around 20% of the UK GDP



c) The manufacturing drivers for primary and secondary processing industries can be summarised as follows.

Manufacturing drivers for primary and secondary processing industries

	Primary	Secondary
Competition	Price	Features, service
Innovation	Very low	Very high
Manufacturing emphasis	Efficiency	Flexibility, responsiveness
Markets	Low growth, cyclical	High growth, relatively steady
Demand variety	Low and/or predictable	Variable and volatile
Products	Bulk or large units	Packaged in small units

d) Continuous or discrete media differ in the means by which they are managed, the following table identifies the different approaches for handling, automation and inspection of such products.

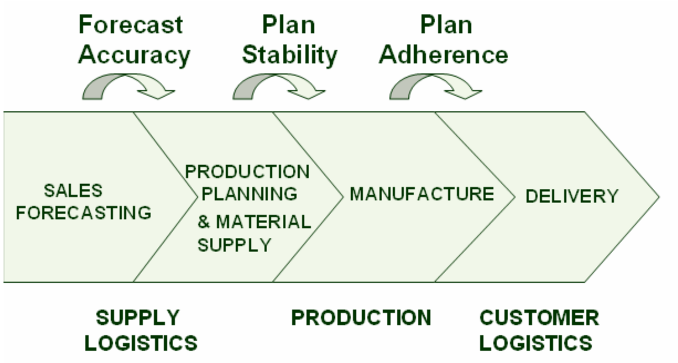
	Continuous	Discrete
Handling	Gravity, pressure, pump, blow	People, machines, robots
Automation	Sensors, actuators, analytical instruments	Specialised machinery, robotics
Inspecting	In line instruments	Pick, measure and test

.END OF ANSWER

Question 6

This question was set by Dr. Bill O'Neill and relates to information delivered in the MET II Process Module.

a) A typical supply chain for a company making FMCG is shown below. It consists of the following components. Sales forecasting, this provides likely demand data for the products in question. This information is input into production planning and material supply operations that develop the necessary production operations for manufacturing the product. The product is manufactured and then delivered to the customer under a logistics procedure which provides the goods to the customer at the right place, right quantity and the right time.



b) "Make to Stock" is a term that describes the need to manufacture products for a customer with a very short lead time. In this case the lead time could be as short as 24 hours from order to delivery. This operating practice places particular demands on the manufacturer. There is a need to develop accurate forecasts in order provide sufficient production and maintain stock levels at the appropriate level. "Make-to-stock" operations often experience variable demand levels that are affected by seasonal issues such as holiday periods or the weather. Retailers often implement promotional campaigns that significantly affect their order levels. Forecasting also allows a manufacturer to plan their own demands on their suppliers in order to obtain sufficient raw and packaging materials. In addition it allows the expected demand on the factories, individual production lines and labour both in the short term and long term. Sales forecasts are also used in business forecasting models to determine operating costs and profit levels.

c) (i) Master production scheduling is the activity (in an MRPII or ERP environment) which follows Sales and Operations Planning. The high level demands agreed at S&OP are taken by the Master Production Scheduler, and loaded into the system to produce detailed materials requirements plans and shop floor schedules. The Master Production Scheduler resolves problems (such as insufficient lead-times, bill of material problems and capacity shortages) before issuing the MPS. Once released the MPS drives material supply through MRP and BoMs and creates shop floor schedules through routings. There may be specific and more detailed shop floor scheduling process which operate “below” the MPS in which case the MPS provides the inputs to these processes.

c) (ii) Materials Requirements Planning (MRP) is the process which orders the supply of materials to shop floor operations to meet the requirements of the Master Production Schedule. MRP is a component of MRPII (Manufacturing Requirements Planning) and is a computer based system. MRP operates by using Bills of Material (BoMs) to determine the quantities of components or materials needed to fulfil the MPS and their timings and locations (through Routings).

c) (iii) Finite Capacity Scheduling means that when the Master Production Scheduler or Shop Floor Scheduler is planning production to meet requirements of the Sales and Operations Planning process, the actual limitation on throughput of each stage in the factory is taken into account. Note in this context that MRPII at its simplest is based Bill of Materials and Routings which do not necessarily reflect fully constraints on capacity at each stage of the production process. Rough Cut Capacity Planning is the high level view of capacity usually taken by the Master Production Scheduler at Sales and

END OF ANSWER