Paper 1, June 2017 – Questions 1 & 2 – Cribs

Question 1

1. (a) (i) While multiple definitions exist, because of the material discussed in the course, it was most important to show an understanding of the definition in terms of using renewable feedstocks to make polymers. Excellent answers would also note that in fact there are other definitions in use, including polymers which biodegrade and also polymers that are used to interface with the human body and are biocompatible.

There are a range of polymers that could have been chosen as examples. Those covered in the course or from additional reading were all acceptable. *Only brief notes were required in these answers.*

Starch-based biopolymers could have been noted as a category. Applications noted include as a substitute material for expanded polystyrene packing. This has the right density and mechanical properties while having the advantage of being biodegradable also. Starch-based polymers are used to make films for tunnels or coverings over rows of plants/crops for conserving water. Mechanical properties and biodegradability again were noted by candidates. Most who mentioned starch-based polymers noted it could be used as an additional component blended into other, non-bio polymers, to improve biodegradation. Up to a certain inclusion level, the properties were excellent but then there is a tradeoff between improving degradation at the expense of the mechanical properties. It was also noted by some that starch-based polymers can be used as a substitute for polyethylene and polypropylene, with some food packaging being applications that lead to better biodegradation and ease of disposal of food products.

Polylactic acid (PLA)was noted in particular, with applications in bottles, some fabrics, plastic cutlery and other food packaging. The mechanical properties, similar to polystyrene are important and also the ability to replace polyethylene and polypropylene, especially in terms of mechanical properties and optical properties (good clarity). The biopolymer is resistant to oils and greases so again is very useful for products in contact with foodstuffs. In addition the biodegradation reduces the challenges of disposal as food and polymer can degrade.

Polyhydroxyalkanoates (PHA) was also noted, with applications in cutlery, plastic food containers, a range of consumer products (razors, toothbrushes, shampoo bottles). PHA is often chosen because of its strength or rigidity for these applications. It can also be sent to composting or anaerobic digestion for degradation, which can simplify disposal. Applications could be noted where a replacement is needed for PVC, PE or PP.

In each case, excellent answers gave two example applications with two properties highlighted as important. Answers only required short notes on each.

1. (a) (ii) The answers were divided in two, focusing on reasons for moving towards bio polymers and secondly then discussing the barriers.

In terms of the drivers, one important answer is the unsustainability of fossil fuel based feedstock. The environmental issues with synthetic polymers should also be noted and there are a number of point, such as:

The accumulation of waste in its bulk form in oceans and lakes as a result of poorly managed waste disposal.

Poor disposal management has led to plasticisers leaching into the environment along with other additives. Examples include phthalates (plasticiser) and PBBs which add flame retardancy properties required in many applications.

There have been reports of knock-on effects of these leaching materials in terms of changing reproductivity of sea life and also, once in the food chain, this can lead to health issues in human consumers. Examples were noted, such as the recent news item on plastic particulates making its way into the food chain.

There is a general drive to improve the waste disposal of polymers and enable biodegradability in a wider range of products, which is feasible with biopolymers.

There is a benefit to moving to industrial symbiosis activities and the raw materials of biopolymers can be sourced this way.

There is now also consumer pressure for the use of renewable materials and more environmentally responsible material choices.

In addition, while bio-based polymers have been available for some time, recent research is bringing down costs and making them more attractive for applications.

There are a wide range of barriers and so again, marks were given for briefly but clearly communicating a range of different points.

It is believed that this will need intensive farming and specifically large scale monocultures to be feasible, which can lead to significant issues, such as the exhaustion of nutrients from soils and the large scale use of herbicides/insecticides and other agrochemicals. There is significant competition for the use of land for food or biopolymer (and biofuel) material growth. This was pointed out as a real challenge, considering the significant demands on increasing food production with a growing population globally.

Another barrier is the use of fossil fuel based energy sources in the rest of the production process for agricultural sources. The cost, while reducing due to R&D efforts, is still significantly higher than synthetic polymers. There are significant end-of-life complexities. Not all biopolymers can be handled the same way, with some requiring anaerobic digestion rather than home or industrial composting. Also, the incorporation of biopolymers into blends with synthetic polymers an lead to challenges in identifying a useful recycling route. While the synthetic polymer may be replaced, there is often still a need for the fillers and additives noted for their environmental impact. There are a range of additional answers and again marks were assigned to both the range of answers but also the level of clarity in their communication.

1. (a) (iii) There are many challenges that can be described in this answer. The best answers had clear communication of the points raised, rather than many poorly explained descriptions.

While LCA is standardised framework, it was noted by many candidates that users can interpret differently within this framework, which then makes comparing across studies and final interpretation extremely difficult. The LCA should cover the entire life-cycle: extraction of raw materials to disposal but this is not always the case.

So firstly, there is this flexibility in terms of scope, and secondly within this scope there are areas that are not defined in a standard way. For example, soil carbon/nitrogen dynamics, emissions from composting, the local manufacturing environment and maintenance of equipment can all be interpreted differently.

In addition, there are very location-specific challenges that can be noted in the answer. Farming practices and their resource requirements will be very different depending on location due to climate. Energy production and its environmental impact is linked to the country, energy source and regulations. There will also be an impact from the distances across which materials need to be transported and the disposal routes available.

Some answers gave details on the challenge of identifying appropriate categories of impact and ensuring that metrics across these categories can be compared. Allocation approaches were also noted to be different across different studies.

These are some of the possible answers and include the most common points. An excellent answer covered a broad range and also communicated each point sufficiently clearly.

1. (b) (i) In the definition of this term, the answer should convey that, either due to the intrinsic properties or through additional processing steps, there are materials that have a much better performance for a specific application than competing alternatives. The best answers also gave examples of what such properties may be and products where we find high performance materials. e.g. – resistance to corrosion – strength – stiffness – lightness – heaviness – elastic energy storage – wear resistance – resistance to creep at high temperature. Apart from the example already given in the second half of this question, detailed examples were discussed in the lectures of ultra-strong glass, aluminium drinks cans, vaulting poles and so were the most commonly used in this answer but other valid examples are of course acceptable.

1. (b) (ii) Ball rolling bearings need to allow a very high load-carrying capacity over a long product lifetime. There are very high compressive forces. There are also high shear stresses and the material must at all times remain below the yield point. High yield stress materials are therefore used for these applications to avoid permanent deformation of the ball.

The high performance materials must also be made to extremely high levels of precision of manufacture. For example the roundness needs to have a tolerance of less than 1 μm. This ensures smooth rolling and avoidance of uneven distribution of loads.

The surface roughness is usually produced through grinding to a tolerance of less than 0.01 μm. Again, this reduced friction is essential for the function of the bearing.

The material strength must also be very high to avoid fatigue failure because of the continuous use of these parts for long durations and repetitive cycles.

In terms of processing, it is an important aspect discussed in lectures, that the non-metallic inclusions should be reduced as far as possible. These include oxides and sulphides specifically. Removal of these ensure a long product lifetime. These act as stress concentrators where cracks can be initiated, they can grow under cyclical loading and once they reach the surface can cause pitting an catastrophic failure.

So to extend bearing fatigue life, the oxygen content needs to be reduced. The process noted in lectures is a vacuum arc re-melting technique. This involves an electric arc furnace, operated under vacuum, where the arc is created across an electrode and a melt pool of the steel. This enables melting of the metal, driving out the oxygen content and then solidification of a final solid steel. Excellent answers note the key points about the process and add some extra clarity through the description or diagram.

Question 2. (a) (i) Additive manufacturing (AM) is expected to be advantageous due to the ability to reduce waste involved with manufacturing. Subtractive manufacturing naturally produces waste in a process, whereas additive uses close to the required material.

There is the potential to distribute manufacturing, reducing the need for transport of final products. This compresses the supply chain considerably.

AM also leads to compression of time required for product development, both due to the speed of setting up manufacturing processes but also the ability to trial innovations quickly.

There are advantages for designers and manufacturing engineers because it extends capabilities to more complex, geometric shapes and features that were previously not feasible (e.g. nested structures).

AM is also advantageous because some techniques are low cost and so accessible to a very broad array of industries and also students, hobbyists and entrepreneurs.

While there are significant material limitations, the range of materials and final material properties have been rapidly increasing, allowing end-use parts to be produced in a wide variety of polymers, metals and ceramics.

There are a very broad range of example applications from which to choose.

The applications most often referred to fell under prototyping applications, with the rapid turnaround time and great flexibility of fabrication being noted; or tooling applications, with the importance of flexibility in jig, die or mould design noted; or the direct final part production for spares and repairs applications, with the fine art and jewellery applications noted because of the low demand on rapid fabrication but great advantage of rapidly producing new designs. Aerospace and automotive applications were also noted under this category, but only for applications where there is no need for high throughput manufacturing. The 3D printed fuel nozzle was an example discussed in the lectures. Some also mentioned the fabrication of custom-made medical devices because of the ability to tune for a patient's needs.

2. (a) (ii) A large number of techniques were discussed during the course. It is important to describe the technology clearly and in sufficient detail to understand the principle route to delivering a product. A drawing is acceptable to supplement the answer and provide additional clarity. Benefits and constraints need to be presented for each of the technologies described.

Powder bed fusion, vat photopolymerisation, directed energy deposition, material extrusion, mamterial jetting, binder jetting and sheet lamination were among the main approaches covered.

For example, when discussing powder bed fusion, it is important to note that the material that the final product will be made from is initially in powder form and present in two powder beds. Software is used to use a CAD drawing of the 3D object and reproduce it as a series of 2D layers, starting at the base and working up to the top of the shape. A laser is raster scanned over one powder bed to fuse the powder together to represent that first 2D layer. A fine layer of the powder is transferred from the other bed to then just cover the fused layer and the next 2D slice is then patterned with the laser. Each slice fuses the particles both in the 2D layer but also with the particles underneath. This final, fused 3D object is removed from the powder bed, cleaned of the remaining loose powder, and may undergo additional post-processing.

The benefit is that this approach is very flexible and has been shown to work with metals, some polymers and even ceramics. Also, this approach can make very complex parts because the powder that is not fused can act as a support material adding structure to otherwise hollow shapes.

The constraints include the very slow speed, of this approach, the limit of resolution due to both the influence of the heat affected zone and the particle sizes. Also, this approach does not yet give final structures that are identical to fabrication with standard techniques, due to the different crystallography and porosity.

A second approach may be VAT photopolymerisation. In this case, there is a VAT of fluid polymer and initiator, that drives crosslinking when exposed to focused UV radiation from a laser. Again a 3D image is converted to a series of 2D slices. The first slice is patterned onto the surface of the VAT, this polymer cross-links and so hardens. A layer of fluid polymer is then spread over the top and the patterning process is repeated. There is a shelf within the VAT that is steadily lowered with each layer to allow a final 3D object to be produced. This needs to be carefully cleaned upon removal from the VAT.

This has great benefits because of its high resolution and very good final product finish. It is also a relatively quick process. It is constrained by the very limited range of materials that can be used (photocurable polymers), and the poor biocompatibility of these materials. Also, it can't create very complex 3D structures as the fluid that is not cured can't act as a support (for overhanging structures etc.).

2. (b) (i) The definition was not expected to be delivered *verbatim*, but did need to convey clearly what the candidate understood by the term. Examples from the module include “manufacture of products whose functional features or at least one dimension are in the order of micrometres”, “the creation of high-precision three dimensional products using a variety of materials and possessing features with sizes ranging from tens of micrometers to a few millimetres” and “ the manufacture of products and/or features that have at least two dimensions which are within sub-millimetre ranges’. Excellent answers identified the uncertainty present in defining the term and highlighted the differences as well as providing a definition. Indeed, when defining the term, very clear answers illustrated the definition with example products or applications (cardiovascular and in vitro diagnostic devices, cardiovascular clot removal catheters, portable electronic devices, microscale pumps) and processes (laser machining, photoelectroforming, etc.).

2. (b) (ii) In the move from standard injection moulding to micro injection moulding:

In micro injection moulding, there are separate plastication and material injection stages, unlike standard injection moulding. This means the full volume can be used in the shot.

A very small diameter injector piston is used, to give the small shot size.

There is also low material wastage in this approach and significant scrap savings.

However, while sprue volume is very small, it can be relatively large with respect to the final part.

There is rapid cooling because of the large surface area to volume. This is one of the reasons cycle times are very short

Only a small volume of polymer is kept at a high temperature and so there is low thermal degradation of the polymer, ensuring consistent properties in the final product.

low thermal degradation (only small volume of polymer held at high T)

Tool design is necessarily more complex, due to the micromachining requirements.

These systems often need a much higher pressure because of the flow of viscous fluids through narrow capillaries.

2. (b) (iii) It is important to note that this question is focused on manufacturing a small number of micro-scale components. Because of this, injection moulding (which was covered in the previous question) was not a suitable approach to discuss here.

When describing each approach, it was important to give a clear description detailing the underlying principles of the process, details of the materials for which it is suitable and then a range of benefits and constraints associated with the technique.

For example, an answer could describe micro-scale end-milling, photochemical machining, photoelectrical forming, micro electrical discharge machining, laser machining or 3D printing. Other processes are also acceptable if described to the same extent, these were covered in most detail within the module. It may be noted that the dimensions were not given and so techniques may be more or less appropriate in different scenarios.

To give two examples, when describing a process, such as photoelectroforming or micro milling, a number of points would be present in a very good answer:

The basic process for photoelectroforming would be described (possibly supplemented with a diagram) to highlight (1) the suitability for thin metal components, (2) the application of photosensitive polymer to the surface of a flat underlying material, (3) the use of a mask to let through UV light that will modify the polymer so it can be easily removed (or hardened, depending on the polymer). The polymer that is now "washable" is removed in step (4) through developing and washing steps. In (5), the underlying material (which must be conductive), enables electrodeposition of a metal. This means when all of the remaining polymer is removed (resist stripping), and the underlying material, there is a replica of the pattern in the electrodeposited structure. This can be carried out in repeated stages with etching and forming allowing the fabrication of complex 3D structures. Rather than UV, X-ray lithography can be used to get a higher resolution pattern and make higher aspect ratio products.

In terms of advantages, very high feature precision is achieved. The technique can be used to make very thin structures. Also, this is an industrially scalable process, already used in industry. There is however a limitation as to the materials that can be deposited to a high quality using this technique, with nickel being the most used. Also, it is extremely expensive to move to using X-rays and so the particular design needs to be carefully considered.

If describing end-milling, it is important to note that this is a scaled-down version of a well understood and commonly used fabrication technique. In this case, the workpiece is kept stationary, commercially available micro-scale end-mills are used (down to 10 microns in diameter). The cutting speeds are increased significantly compared to end-milling (around 1 m/s relative speed of workpiece and cutting edge), this could be approximately 200,000 rpm. The system does not use flood cooling but instead relies on spray cooling or gas cooling. The tool life is greatly affected by the cutting speed, with a linear decrease noted (differing slopes depending on materials).

The advantages include the high precision on a very wide range of materials along with the fact that it is a well understood technique. There are constraints because it is difficult to detect tool breakage during use of such small end-mills. The depth of cut is limited because the radius of the tool is very small and leads to the tool appearing blunt. When milling metals and the grain sizes are on the same order of magnitude as the end-mill, materials are no longer homogeneous and this can lead to issues in terms of surface finish and dimensional tolerance. Also, another constraint is that this is a very slow fabrication technique.

Paper 1 Cribs – Question 3

ai) A functional specification is a document that is used when specifying the functionality of an automation project and agreeing the participation of different parties involved (End-Users and Systems Integrators).

The purpose of the functional specification:

The functional specification is a technical document that defines the functional scope of the project. It is written to provide common understanding between all parties, with all statements being unambiguous and testable. It often forms the basis of contractual agreements and is referred to as the bible of the project by helping to eliminate specification creep and project disagreements.

Types of information found in a functional specification:

- Functionality of the automation solution
- Exception (error) handling procedures of the solution
    - Automated recovery processes
    - Processes requiring manual intervention (Operation Assistance)

- Required production rate (e.g. an average of 210,000 products over a 5 day period)
- Required solution minimum uptime (e.g. 90%)
- Required uptime of surrounding equipment
- Number of operators required to run the solution

- Frequency of incoming and outgoing components
- Delivery format of incoming / outgoing components
- Required quality of incoming components

- Services required to run the solution (e.g. 120 PSI compressed Air, 240VAC 10Amps)
- Maintenance schedule to be followed to maintain uptime.

aii) Solution testing is an important activity within any automation project. It is important that the full functionality of the solution is tested. Tests should be performed as early as possible to provide time to remedy any issues that arise (Testing should not be restricted to the final phase of the project).

The majority of automation solutions are made by integrating multiple modules (Units) of automation together to provide an integrated solution (System). It is therefore possible to break the testing process up into two phases, unit testing and system testing.

The testing of the individual modules is known as unit testing. As individual modules are tested and integrated with each other, system tests can be carried out. System tests can evolve as the scale of the system is increased. The sequence of integrating modules together and undertaking system tests is critical. The functional specification can be used to develop a plan to undertake both unit and system testing.

Unit tests should include:

- Unit Functionality / Performance
- Operational Status
- Error Conditions

- Interfaces of both Hardware / Software

System tests should include:

- Integrated Functionality / Performance
- Error Handling / Recovery Strategies
- Interfaces of both Hardware / Software

bi) The project plan has a number of key weaknesses:

Weakness	Addressed by
1) No system testing is shown on the plan.	Incorporate a system test phase at the end of the project (Integration and testing should take around 40% of the total project period). Some unit testing activities could be undertaken by suppliers, helping to reduce the testing time.
2) No provision is provided to address solution concerns about the Injection moulding supplier.	A prototyping activity should be included. This could commence as soon as the specification work has been completed. Design work could not be completed until the end of the prototype activity.
3) The final system build at the valve manufacturer will impact on the peak production period in June.	The final system build has to be split into two activities. Activity 1) Line modifications taking place before the June peak. Activity 2) New system build during the summer shutdown.
4) It is unlikely that the system design work at the valve manufacturer can be completed prior to design work at the injection moulding supplier.	Design work at both the Injection moulding company and the valve manufacturer have to be extended to accommodate prototyping work.
5) Equipment from the material handling supplier will not arrive prior to the summer shutdown.	Tasks undertaken by the material handling supplier need to be carried out earlier.
6) No overlap is shown for tasks being carried out by either of the suppliers. Not realistic in a project plan.	Introduce overlap of tasks to help handover of activities. It's unusual to have a snap change between one process and another.

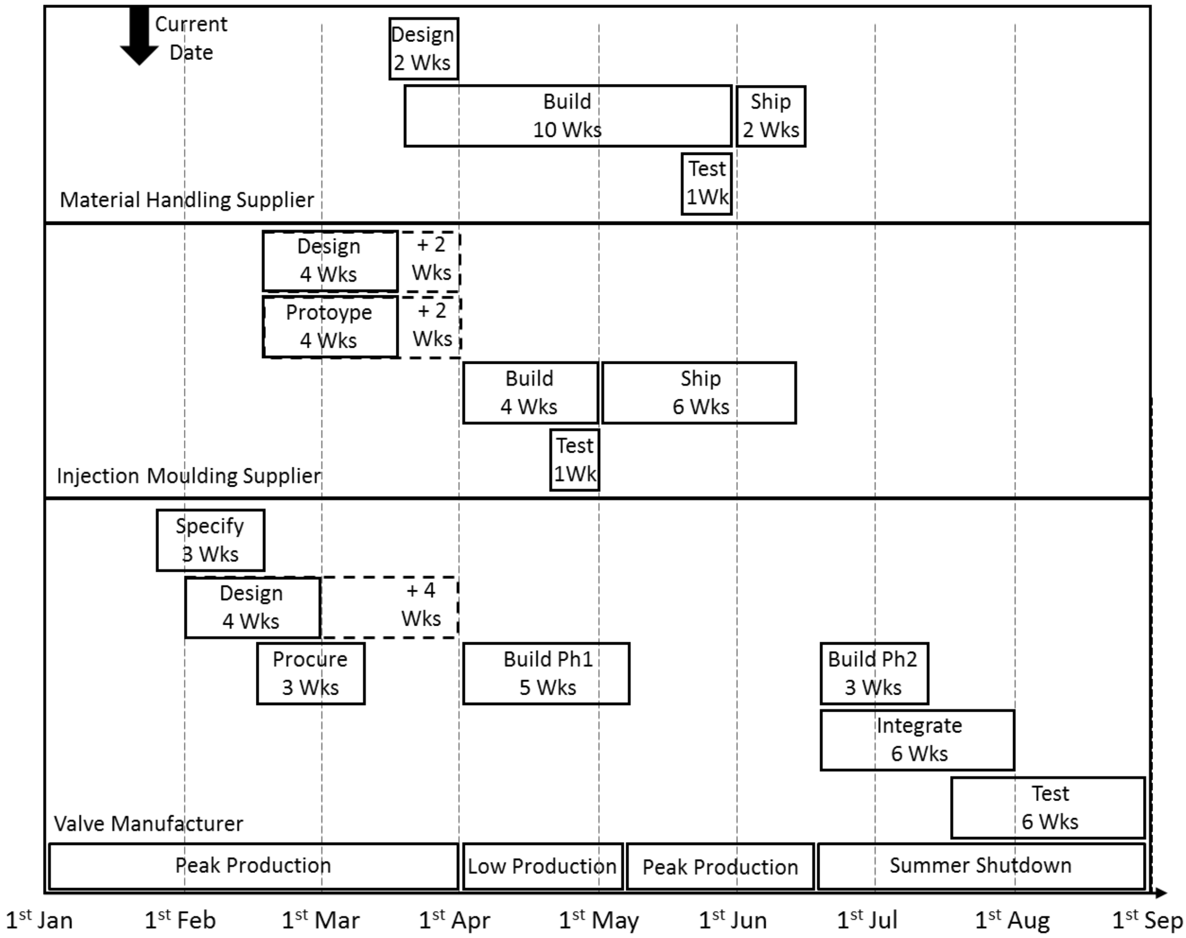
bii) The tasks being undertaken by the Injection moulding supplier are currently on the critical path.

The task being undertaken by the Injection moulding supplier have the highest risk. These tasks need to be pulled forward with additional solution investigation tasks added (Prototyping).

Until the Injection moulding supplier has a working solution the design phase of the other project suppliers should not be completed (This is to accommodate late changes).

Final system build has to be split into two activities to ensure that it can be carried out during non-peak production periods.

The proposed time plan provides extra time for the Injection moulding supplier to develop a solution but moves the material handling tasks on to the critical path. Note the material handling build process has to commence before the project design phase is finished. This risk is balanced by the fact that the solution being requested is fairly standard and readily available.


Current Date
Design 2 Wks
Build 10 Wks
Ship 2 Wks
Test 1Wk
Material Handling Supplier
Design 4 Wks
+ 2 Wks
Protoype 4 Wks
+ 2 Wks
Build 4 Wks
Ship 6 Wks
Test 1Wk
Injection Moulding Supplier
Specify 3 Wks
Design 4 Wks
+ 4 Wks
Procure 3 Wks
Build Ph1 5 Wks
Build Ph2 3 Wks
Integrate 6 Wks
Test 6 Wks
Valve Manufacturer
Peak Production
Low Production
Peak Production
Summer Shutdown
1st Jan
1st Feb
1st Mar
1st Apr
1st May
1st Jun
1st Jul
1st Aug
1st Sep

Version AP/1

CRIBS – METIIB paper 1

4 (a) The coefficient values give the coefficients of each variable of the linear equation describing the gross earnings. For instance, a £1m increase in production cost yields an increase of £2.85m in gross earnings on average. The regression results therefore give the following regression equation for estimating or predicting the gross earnings: EARN= 7.84+2.85xCOST+2.28xPROM+7.17xBOOK+*e*.

All the variables are significant (t-stats greater than 2 in magnitude and p-values < 0.1) and a high R^2 = 96% explains much of the variation in gross earning. Hence the model is useful in estimating the gross earnings of a movie. However, the sample size of 20 movies is a concern considering the large number of movies produced in Hollywood.

(b) Predicted earnings $EARN_1 = 7.84 + 2.85\times6 + 2.28\times3 + 7.17\times1 =$ £38.84M with book versus $EARN_2 = 7.84 + 2.85\times6 + 2.28\times3 + 7.17\times0 =$ £31.68M without the additional earnings obtained when a movie is based on a book.

(c) The analyst needs to compare the two samples – one with movies where the BOOK variable is 0 and the other where the BOOK variable is 1. Thus two samples are created:

BOOK=1	BOOK=0
35	28
50	20
75	15
60	45
50	24
48	34
82	50
58	63
30	37
45	
72	
Mean: 54.2; Stdev: 16.4	Mean: 35.1; Stdev: 15.4

Null Hypothesis H_0: $m_1 - m_2 = 0$

H_1: $m_1 - m_2 \neq 0$

Test statistic = 54.2-35.1 = 19.1

St. error =

$$\sqrt{\frac{15.4^2}{9}+\frac{16.4^2}{11}} = 7.13$$

Standard error of the difference is 7.13.
Students can then do either one of the following.
Check the upper and lower bounds of within 95% confidence:
Upper confidence interval: 33.09
Lower confidence interval: 5.14
Since zero is not in this interval, reject the hypothesis that the true means are the same. Thus, earnings of a movie based on a book and not based on a book are not the same.

Alternatively candidates can calculate the distance of the test statistic, 19.1, from 0:

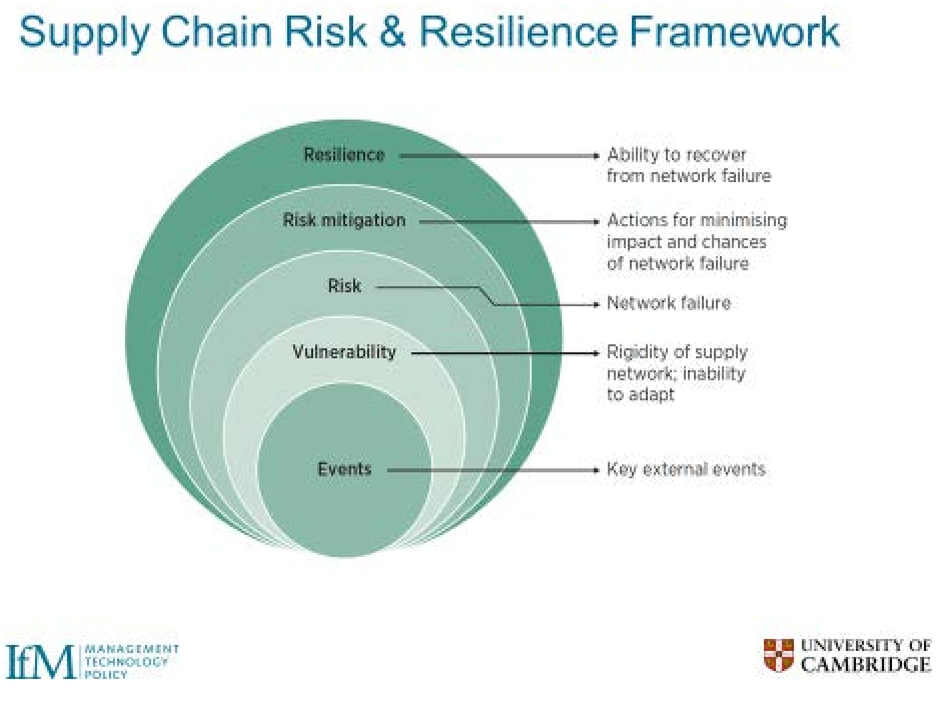
t-stat = (19.1-0)/7.13 st.errors = 2.68 st.errors

Greater than 1.96 so reject H0. Thus being based on a book has a significant impact on earnings.

(d) £7.84 millions. This figure is meaningless (COST=0, PROM=0, BOOK=0 is a data-point well outside the data range used to estimate coefficients of model).

6 (a)

The supply chain risk and resilience framework explains the concept of event, vulnerability, risk and resilience. At its centre is ‘event’ (such as climate change, war, new regulation or financial crisis), which might have significant impact on supply networks. Next is ‘vulnerability’, which is associated with structure of supply network and particularly its lack of flexibility. ‘Risk’ appears when key events and vulnerability interacts with each other, which leads to supply network failure. Next is ‘risk mitigation’, which is an action or set of actions taken by companies to minimise either impact or changes (probability) of risk. ‘Resilience’ is an ability to recover from network failure, which is achieved by continuously changing supply networks in response to risks by using risk mitigation approaches, such as adopting new processes and /or practices or by reconfiguration



[I expect that the most of the students will answer this question. The best student will be provide clear differences with examples of each concepts. These concepts are presented in the lecture material]

(b) (i)

Risk exposure = Probability of typhoon risk * Impact of typhoon risk on company A's supply chain
Probability of typhoon risk is given = 30%

Typhoon risk exposure to Company A:
Impact of typhoon risk: This risk break end to end supply chains for 5 days. Based on the description. The typhoon risk will shut down Company A's India operations for 3 days because Company B will supply parts from its finished parts inventory. One day value of India operations is £2 million. Therefore, the impact of typhoon risk on company A's supply chain is 3 * £2 million = £6 million

The typhoon risk exposure to Company A = 30%* £6 million = £1.8 million.

Typhoon risk exposure to Company B:

Impact of typhoon risk: This risk break end to end supply chains for 5 days. Based on the description. The typhoon risk will shut down Company B's India operations for 5 days because Company B does not keep raw material inventory. One day value of Company B operations is = £600,000 per year / 365 days = £ 1,643.83. Therefore, the impact of typhoon risk on company A's supply chain is 5 * £1,643.83 million = £8,219.15

The typhoon risk exposure to Company A = 30%* £8,219 = £2,465.75.

(b) (ii)

- Risk of running out of raw materials because of critical raw materials (either rare or single sourcing) are required.

- Risk that inappropriate working environment (poor conditions, insufficient breaks, long working hours) would affect operations of Company A because it is located in developing country (India).

- Risk that natural disaster would affect Company A's operations because of its tier 2 supplier is based in high probability of natural disaster zone (Japan).

- Risk of operations disruption due to terrorist attacks because Company A is based in area facing high probability of terrorist attacks (India)

- Other indirect risks due to disruption from above mentioned direct risks in Company A's operations may include – reputation risk, brand loyalty risk, loss of market risk and litigation risk.

(b) (iii)

- Keeping safety stock and multi-sourcing will minimise risk of running out of raw material

- Moving operations to a developed country and developing world class working environment will mitigate risk of in appropriate working environment

- Multi-sourcing or finding/moving tier 2 supplier from natural disaster zone will mitigate risk of natural disaster

- Moving operations to a location where terrorist risk is less and investing in anti-terrorist securitise will mitigate risk of in appropriate working environment

- Above mentioned mitigations will mitigate indirect risks as well

- Taking insurance protection against all the risks will minimise the impact of all the identified risks

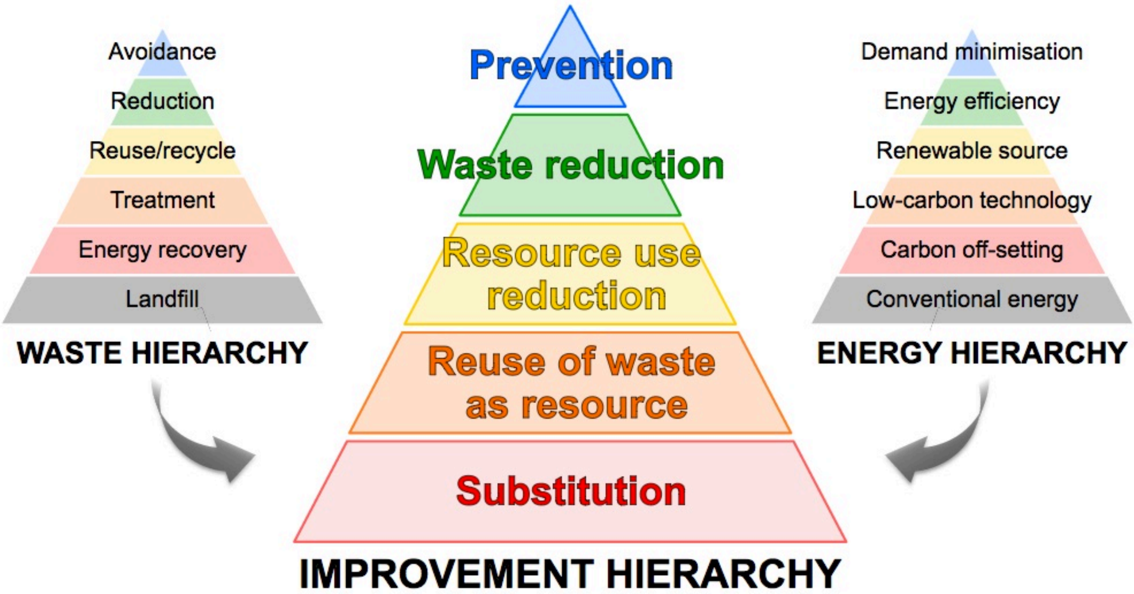
[I expect that the most of the students will answer this question. The best student will provide examples of risk mitigations such as keeping two suppliers for the same part, shifting exiting factory to different locations; increasing security guards and surveillance, etc. They will clearly mentioned supply chain risks rather than events]

METIIB Paper 1 2017
Question 5
(a) (i) LCA is aimed at providing a measure of the total environmental impact of the kettle, from material production, manufacture, use and disposal. It is particularly useful for comparing the impacts of products, as much like-for-like as possible. For a kettle, one might compare different materials or production technologies.
(ii) Outputs can be generated under nine environmental themes (students were not expected to remember details for these, but they are stated here for completeness):
Abiotic depletion potential; Energy depletion potential; Global warming potential; Ozone depletion potential; aquatic/terrestrial ecotoxicity; acidification potential; human toxicity; photochemical oxidant creation; nitrification potential.
All have different metrics, so combining them is not straightforward. Most studies choose only some of the headings, and tend to keep the figures separate under them. Assessment of impact therefore requires some judgment, such as which metrics are most important.
The choice of system boundaries is crucially important in any LCA. There is some flexibility about how this is done, so it is important that similar system boundary choices have been made when making comparisons between different LCAs. Similar care should be taken over allocation and choice of functional unit.
(iii) The use stage will dominate: the amount of electricity used.
Some steps can be taken to improve kettle efficiency: thermal insulation of the kettle; in hard water areas, ensure no buildup of limescale on the heating element. But the way in which the kettle is used can be optimized: e.g. include a water measure scale to encourage thought about volumes of water heated.
Geography is a big factor: the environmental impact of electricity generation is *very* different in different areas, depending on the generation method (ranging from the high CO_2 footprint of coal-fired power stations to 'green' renewables, such as wind and solar).
(iv) Material production will have the biggest impact. This can be minimised by reducing the amount of material, but this will tend to reduce the longevity of the product so a balance must be struck. There is a relatively small end-of-life impact: metals can be recycled, but separating materials in a product such as a kettle is not straightforward.

(b) The resource hierarchy is summarised in these two slides, which provide the basis for good answers. Specific and relevant examples chosen from students' own experiences were given credit.

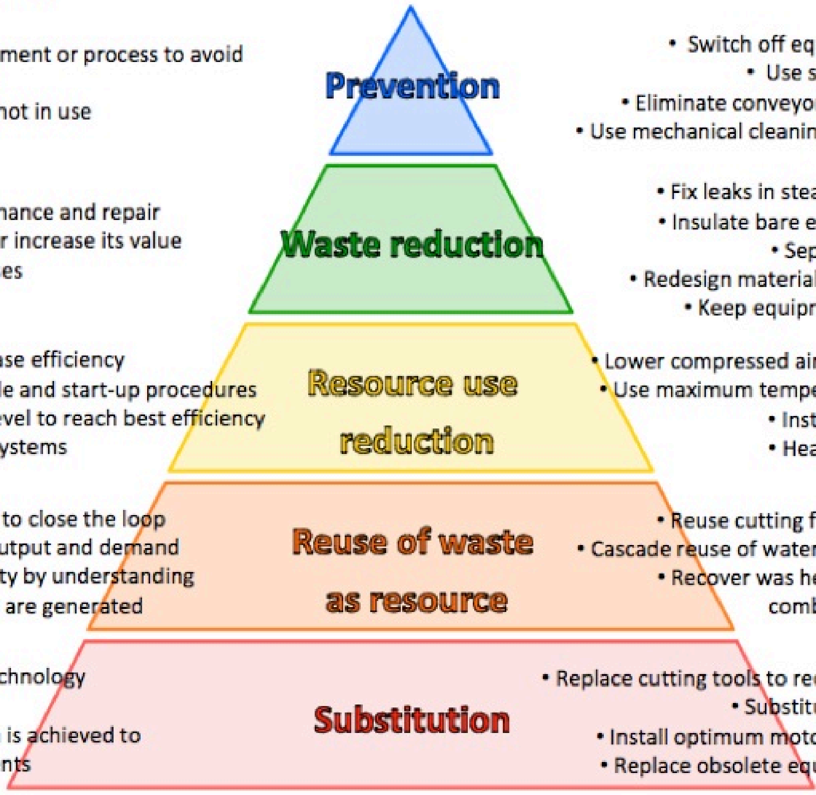
Improvement strategies

IMPROVEMENT HIERARCHY



Improvement strategies

TACTICS & BEST PRACTICES



TACTICS

Generic rules for resource efficiency

Prevention

- Eliminate unnecessary equipment or process to avoid resource use completely
- Switch off equipment when not in use

Waste reduction

- Good housekeeping, maintenance and repair
- Sort / treat waste to retain or increase its value
- Optimise layout to avoid losses

Resource use reduction

- Minimise demand and increase efficiency
- Optimise production schedule and start-up procedures
- Match demand and supply level to reach best efficiency point of use of equipment / systems

Reuse of waste as resource

- Convert waste into resource to close the loop
- Look for compatible waste output and demand
- Understand reuse opportunity by understanding where and when waste flows are generated

Substitution

- Replace resource input or technology (renewable and non-toxic)
- Change the way the function is achieved to allow larger scale improvements

PRACTICES

Actions for resource efficiency

Prevention

- Switch off equipment during non-production
- Use stand-by mode during inter-shift
- Eliminate conveyor belts and gravity feeds instead
- Use mechanical cleaning to avoid the use of detergent

Waste reduction

- Fix leaks in steam and compressed air network
- Insulate bare equipment to reduce heat losses
- Separate waste to enable recycling
- Redesign material flow to minimize mass transfer
- Keep equipment clean and floor space clear

Resource use reduction

- Lower compressed air pressure to minimum required
- Use maximum temperature allowed for cold storage
- Install controller on electric motors
- Heat water during off-peak periods

Reuse of waste as resource

- Reuse cutting fluid after separating from swarf
- Cascade reuse of water in multi-stage cleaning process
- Recover was heat from equipment to pre-heat combustion air and boiler feedwater

Substitution

- Replace cutting tools to reduce energy input & waste heat
- Substitute cutting fluid to enable reuse
- Install optimum motors for peak operating efficiency
- Replace obsolete equipment with newer technology