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Q1. a) Additive manufacturing process consists of five stages:

① • Solid modelling (CAD) - Solid modelling is the first stage of creating a component where a CAD/CAM package is used to produce part body features & designs

② • Converting the file to .STL - When producing a CAD model the use of a printing process may be required in order to produce mock-up designs. Saving the CAD file as an .STL means that it can be recognised by other machine software in order to print using a Rapid prototyper 3D printing machine. The .STL holds information such as coordinates, surface quality (Triangulation), support pillars etc.

③ • Slicing the file - To produce a part using a rapid prototyper, involves having a printing process where the machine prints in a series of layers in order to build the required component. The so called 'Slicer' depends on the user discretion where he/she may select a thickness, speed, quality etc.

②

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④. Build model - The printing process
This process is controlled by a set of parameters called AM technology. These parameters are produced when the .STL file is sent to the machine. From here the machine can begin the printing process and starts the build-up of layers.

⑤ Clean & Finish - The final stage is the removal of the product from the machine. The component is normally built on a carbon based foam which is the base/platform for the component. This can be simply parted as well as the support structure that was ~~part~~ ~~part~~ put in place in order to support the printing process. The finish of the parts can be determined further by sanding or polishing triangulated surfaces.

b) The three types of raw material used for ~~additive~~ additive manufacturing are:

① - Liquid based - The liquid raw material is printed using a nozzle which is then left to cure to a solid state. One example of this is Stereolithography (SLA).

③

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② - Solid based - These come in Solid State raw which are usually wires, pellets, rolls or laminates. This is a modern method and is commonly known as 3D printing. This is one example of Solid based additive manufacturing where it follows similar principles to ink jet technology. Each build up of layer is used by thermoplastic which is expelled using support material to achieve a certain geometry

③ Powder based - This is technically Solid based, however it involves a grain-like powder that uses a laser which melts a thin pre-heated layer of heat-fusible metal powder to form a model slice. This process is known as Selective laser melting (SLM)

c) Support structure is used to support floating geometries when additive manufacturing. It can be used to help separate the part from the base/platform. Many additive processes use support structure however two particular processes do not require it. Powder based processes

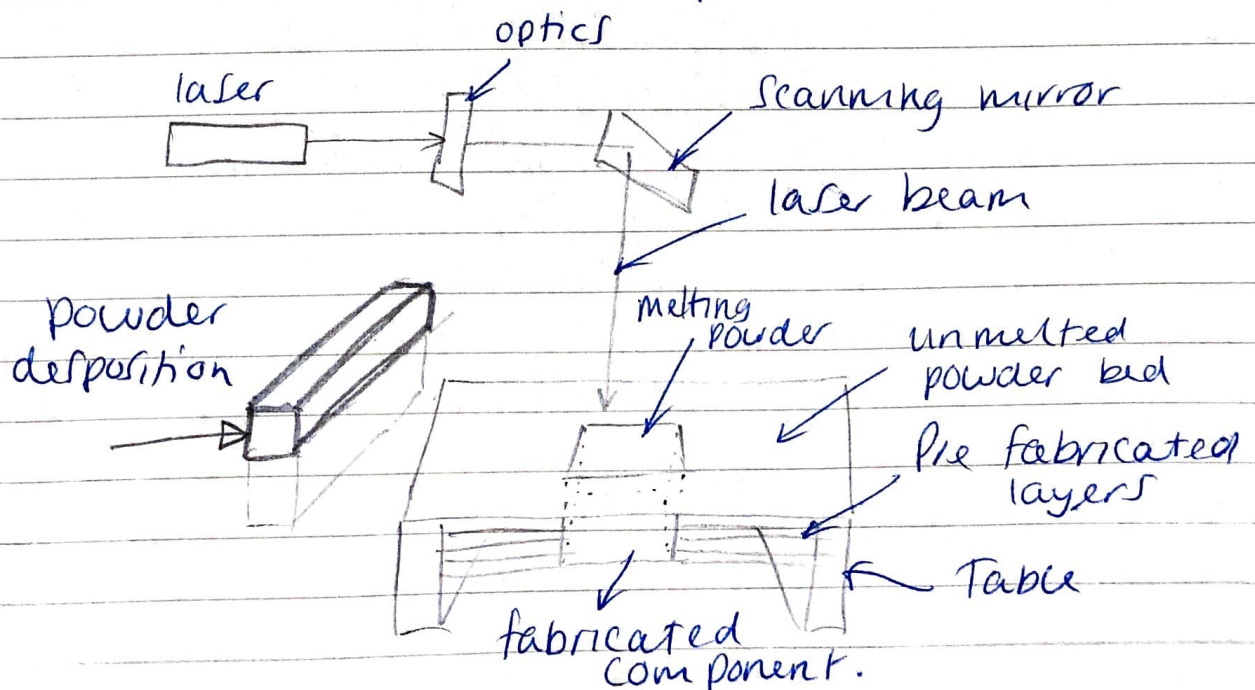
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Such as Selective laser sintering (SLS) and Selective laser melting (SLM) do not require support. ~~SLS does not require support because the~~ Both processes do not require support because they use a supporting bed which forms the selective shape / geometry.

~~The additive manufacturing process that can create metallic parts is called investment casting. A sketch below can demonstrate the process:~~

d) SLM can be used to create metallic parts. The selective laser melting process is similar to SLS where a CO₂ laser melts a thin pre-heated layer of heat-fusible metal powder to form a model slice. The metal powder is melted rather than sintered giving parts that are 100% dense. The process can be shown below.



5

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Q2. a) Robots are not designed to work with humans where Cobots are designed to specifically work alongside human beings. A collaborative robot or Cobot are used in situations where human interaction is required. Advantages of Cobots are that they are easily moved into different areas of production and that they are programmed to not accelerate faster than 250mm per second which makes them far safer than a normal industrial robot. The advantages of a Robot are that they can be used to assist additive manufacturing techniques, also can be used in hazardous environments which makes it safer for human beings. The disadvantages of Robots are that they cost a lot of money to maintain & repair. Also they cost much money when they breakdown as if one robot in a line is broken, the whole line is effected by it. The disadvantages of Cobots is that they cannot lift more than 15kg where lifting robots can lift 100's of kilos. Also, a cobot is far less productive ~~as~~ due to its speed limitations.

b) Industrial robotics is having a massive impact on manufacturing companies because they can work in hazardous environments, they can perform a number of different tasks and they do not get tired or distracted.

⑥

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15/05/20

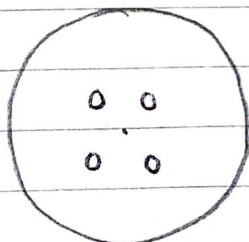
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b.) This would be a great investment for company as they:

- Reduce capital costs - Save energy, H & S equip.
- Increase production rates - 'lights-out' production
- Improve working conditions - upskill employees.
- Reduce operating costs - Overhead $\rightarrow$ competitiveness
- Increase manufacturing flexibility - Number of tasks can be performed by a Robot.

c) Robotic movement can be mechanical, hydraulic or Pneumatic, or a combination. These mechanisms have a role to control the end of arm tooling (EOAT), however each mechanism have either slippage, backlash or both. Slippage occurs when friction or other forces inhibit motion. Backlash occurs when there is imperfect contact between two components in the power train. A sketch can be shown below:

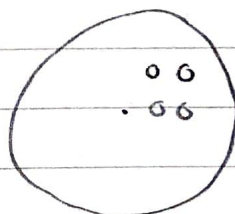
A



High accuracy

High repeatability

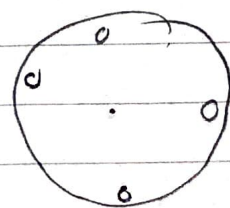
B



poor accuracy

High repeatability

C



poor accuracy

poor repeatability.

⑦

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15/05/20

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- c) The sketch shows the different circumstances that may occur when slippage or backlash are present.
- d) Robots are being integrated with additive manufacturing to produce large scale parts that have increased working envelopes drastically. Robots can be placed on trackways to allow them to increase the work envelope making it an endless additive process. Due to the development of Robotic additive manufacturing, NASA are developing a method to produce 'moon houses' on the moon by using the Silicon based dust that is present on the moon. Using this Silicate, NASA are attempting to use SLS in order to produce real life building by utilising Robotic deployment on the moon.

Q3. a) The four phases of Industrial revolution are

Phase ① - Steam Engines. In 1712 Thomas Newcomen developed the atmospheric engine in order to pump water out of a tin mine. James Watt discovered that the atmospheric engine of Newcomen's was inefficient and that some of the steam could be reused in order to increase efficiency & power of the steam engine.

⑧

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James partnered with Mathe Boulton
to commercialise the new efficient
engine which sparked the first industrial
revolution.

Phase ② - Michael Faraday invented the
first electric motor which meant
machines during the time could have
independent power instead of relying
on horse power. This initial electric
motor sparks our second industrial revolution.

Phase ③ - Computers were developed.
During the second world war, seen
massive development with numerical
control. In the 1960's, saw the very
first main frame computers that helped
the first moon landings. From these computers
came development in numerical control.
Onwards came industrial robots and
in the 1990's saw 2D & 3D modelling
with stress analysis.

Phase ④ - Advanced automation has
hit the modern processes where ~~company~~
lean manufacturing is most important.
Saving time, cost and waste is the
key factor in today's era. Efficiency is
the vital component of any company.

b) The 4 V's of Big data:

Volume - Capacity to handle enormous amounts
of data per second is required.

Variety - Different forms and sources of
Data such as 'wearables' that

9

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b) Incorporated.

Velocity - Real time analysis - not historical data.

Veracity - Accuracy. Reliable information will inform and facilitate decision making.

The 4 V's are the concepts that refer to data sets so large that traditional computer applications are insufficient.

c) Internet of things (IOT) is a concept that is based on the interconnection of any product with any other around to it. These devices are designed to transfer data to a network without human intervention. Industrial Internet of Things (IIOT) are products that are more suited to extreme conditions. These products are usually corrosion resistant, waterproof, have their own monitoring system and have long lasting batteries. Both of these ideas have a partnership with the influencing 5G network that is soon developing. The 5G network has a big influence on the IIOT's because the 5G network will be able to ~~develop~~ handle more devices, have high speed connectivity with low latency and will have a greater coverage worldwide. This will revolutionise the IOT's and the IIOT's.

(10)

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15/05/20

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- d) An example of a recent case study is RFID tags. This has had ~~a~~ a revolutionising influence on the Industry 4.0 because they help monitor information that can be monitored remotely. This has helped monitor hospitalised patients, tracking released prisoners, it is also used on aircraft to monitor food that is being carried on flights. The RFID tag is essentially a geolocated system / software that monitors the loading and unloading of items or people. This has been more influencing for Industry 4.0 as the information gathered is remotely accessible which reduces costs, employees and time to research the information needed.

- e) Industry 4.0 can be analysed by its advantages & disadvantages as below:

Advantages:

- ① Efficient manufacturing; Environmental Sustainability, ~~Physical~~
- ② Physical work reduction (Robots)

Disadvantages:

- ① Security of Information / Data
- ② Production process may be halted if one system fails.

⑪

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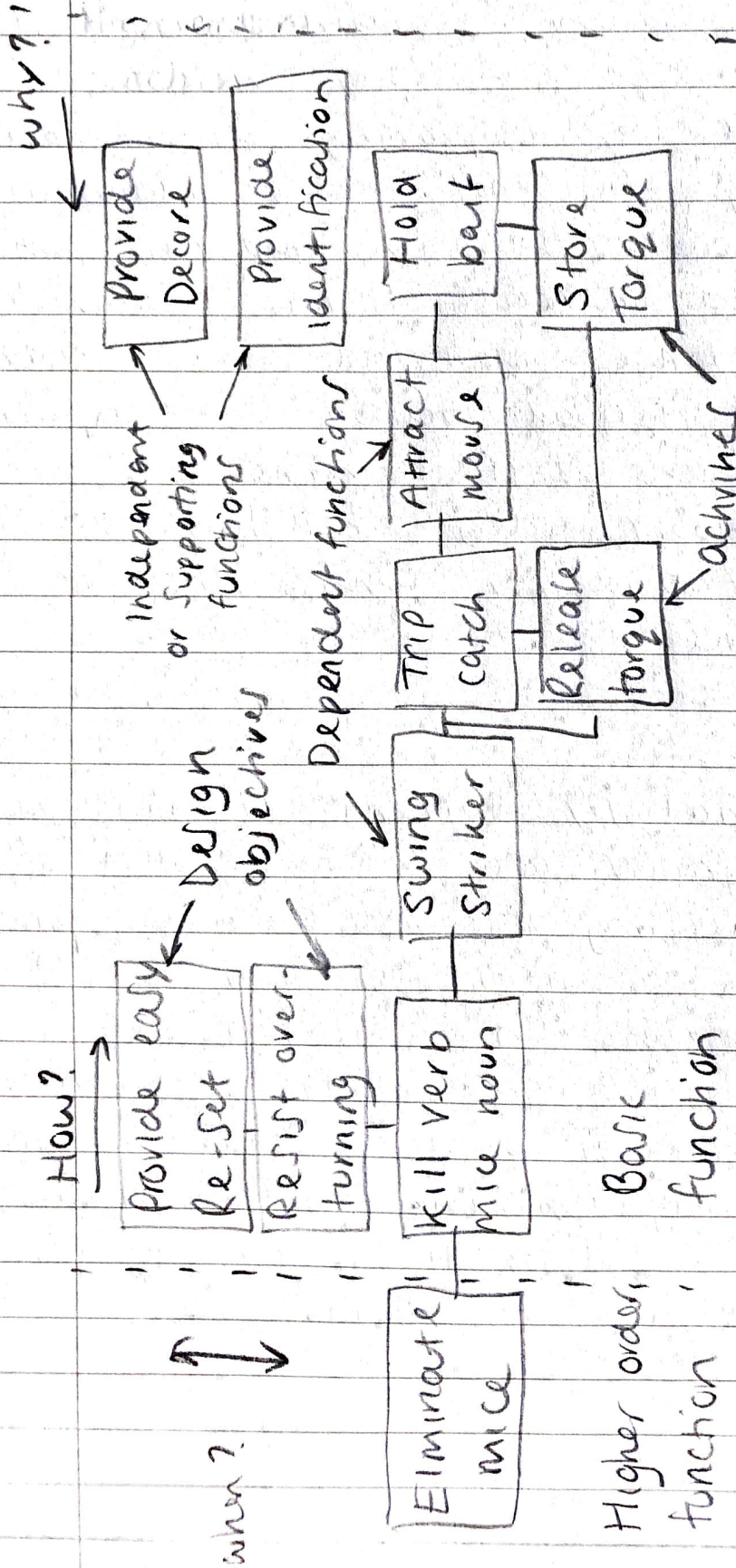
Q5. a) Value engineering is a systematic method to improve the value of a product by an examination of its function. Value can therefore be manipulated by improving the function or reducing the cost. Lean manufacturing has very much been an impact upon Industry 4.0 because it has removed any waste in time, material etc. Robots have been a good value to companies as robots are self-learning and can work 24 hours a day. This has reduced the cost of products which has left them more valuable.

b) Function Analysis Systems Technique (FAST) diagrams are a tool used in value engineering to provide a graphical representation of how functions are linked or work together in a system to deliver the intended goods or service. This technique is used to reduce cost without losing function. A sketch can be shown to illustrate a FAST diagram on the next available sheet.

12

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b) FAST Diagram of mouse trap:



(13)

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15/05/20

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- b) Products that have benefitted from value analysis include flat screen TV's and ~~flighters~~ Laptops. Prices of both have drastically dropped due to the power of value analysis.
- c) The Boston matrix is a means of analysing the product portfolio to make informed market strategy decisions. The products are categorised as: question marks, stars, dogs, cash cows. These categorised topics allow companies to analyse their product and predict its market growth using the Boston ~~matrix~~ matrix. This also allows companies to analyse the product life cycle where they can highlight ~~their~~ their product's potential in the market.
- d) The IOT's is having an influence on product lifecycle management because the modern devices have monitoring systems onboard which allow manufacturers to adjust their product to the market needs. PLM systems is a good example of this because these systems are installed to analyse the system data management that allows companies to analyse their data and adjust their products lifecycle.