Oxford Cambridge and RSA

A Level in Design and Technology:

H404/02 Problem Solving in Design Engineering

Resource Booklet

Practice Paper – Set 1

Time allowed: 1 hour 45 minutes

You must have:
- the Question Paper

INSTRUCTIONS
- You must read this Resource Booklet through before answering any questions.
- The recommended reading time for this Resource Booklet is **35 minutes**.
- This Resource Booklet is to be used when answering all questions.
- The question paper tells you when to refer to the information contained in this Resource Booklet.

INFORMATION
- Do not send this Resource Booklet for marking, it should be retained in the centre or recycled. Please contact OCR Copyright should you wish to re-use this document.
- This document consists of **8** pages. Any blank pages are indicated.

DC (LK/CGW) 182922/1

Turn over

The stimulus in this booklet relates to issues and opportunities encountered through the introduction of new technologies in medical science.

Prosthetics (Artificial Body Parts)

John Nhial was 16 years old when he was seriously injured, treading on a landmine in South Sudan while he was carrying out his morning routine of collecting water.

His comrades carried him back to his camp but there was hardly any medical care available. It took 25 days before he received proper treatment during which time his condition worsened. Nhial's life was saved when he was flown out of the area and handed over to a Red Cross team.

He now lives in a refugee camp and is dealing with life positively through playing basketball for his country. Though he has a positive outlook, he relies on a prosthetic leg to struggle around the refugee camp. Reaching the most basic services often entails long walks but at least his hands are free to carry things such as food and water unlike people on crutches.

Such stories of lives devastated by conflict or disease are all too common in developing countries. The loss of an arm or leg can be tough anywhere but for people in poorer parts of the world it is especially challenging. The World Health Organization (WHO) estimates there are about 30 million people like Nhial who require prosthetic limbs, braces or other mobility devices yet less than 20% have them.

Prosthetics can involve a lot of work and expertise to produce and fit and the WHO says there is currently a shortage of 40000 trained prosthetic specialists in poorer countries. There is also the time and financial cost to patients who may have to travel long distances for treatment that can take five days to assess their need, produce a prosthetic and fit it to the affected limb. The result is that braces and prosthetic limbs are among the most desperately needed medical devices.

The Design and Development of Prosthetics

Each patient who has undergone an amputation is unique which means that each prosthetic limb must be custom designed and built to fit the patient's body. The design and production process for prosthetics involves a number of steps to create an effective and functioning artificial limb.

Taking measurements

Before the specialist can begin to design the prosthetic limb, he or she must take precise measurements. The difference in measurements when the patient still has swelling and when the wound has healed needs to be taken into account.

Modelling prosthetic limb

After the wound has healed and swelling has subsided the specialist takes a plaster mould or fiberglass cast of the affected limb which serves as a guide for building the prosthetic limb. Then the specialist transforms this hollow cast into a positive model of the patient's limb using plaster, water and vermiculite. Next, the specialist engages in the process of modifying the positive model to reflect the design requirements and to create a wearable interface.

Developing prosthetic limb for final use

Once the appropriate fit is achieved, the plastic socket will be transformed into a more durable socket and assembled to form the definitive artificial limb. Many things must be taken into consideration when designing the artificial limb such as the patient's overall health and the location of muscles, tendons and bones in the affected limb.

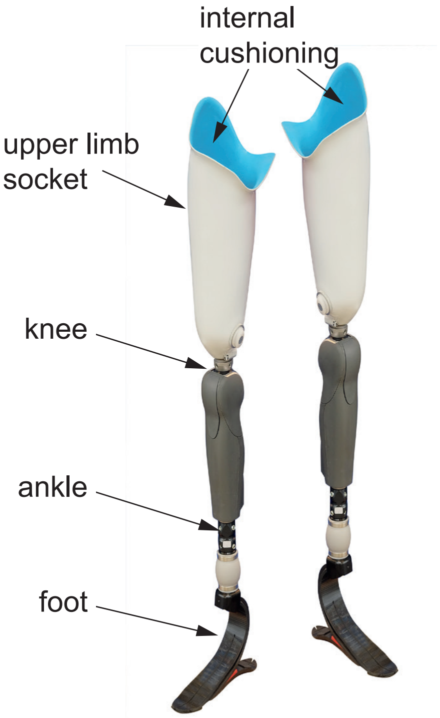

Fig. 1 Parts of a prosthetic leg

3D Printing in Medicine

3D printing has been revolutionising many aspects of medicine in the same way that it has impacted other industries. This technology is well-suited to resolving medical issues as the solutions required need to fit a patient's specific shape and size.

Fig. 2 3D-printed body parts

Experts have developed 3D-printed skin for burn victims, facial reconstruction parts for cancer patients and implants for pensioners. The fast-developing technology has formed millions of customised hearing-aid shells and ear moulds. On a daily basis, it is also producing thousands of dental crowns and bridges from digital scans of teeth, thus replacing traditional wax modelling methods that had previously been used.

A hospital in South Sudan is trialling the use of 3D-printed prosthetic limbs to treat injured refugees. The technology allows an artificial limb to be designed and built within 24 hours and at a fraction of the cost of more traditionally-made prosthetic limbs. A printed prosthetic limb can cost around £20 rather than the hundreds or thousands of pounds associated with the more traditionally made versions currently available. The team is using a high-end 3D printer costing around £2800 which is capable of printing in a variety of materials.

Fig. 3 shows a typical trial prosthetic limb made up of several parts and plastics. The first part is a socket where the upper arm of the prosthetic limb is attached to the affected limb of the patient. This is printed in thermoplastic polyurethane, a flexible plastic which can be made to fit the patient comfortably, based on a 3D scan of the affected limb. The forearm part is made from a firmer plastic while the hand is made from polyurethane as some flexibility in the hand and fingers is useful.

The designer engineers from the hospital in South Sudan are wanting to explore interchangeable hands that enable task-specific functions to be undertaken.

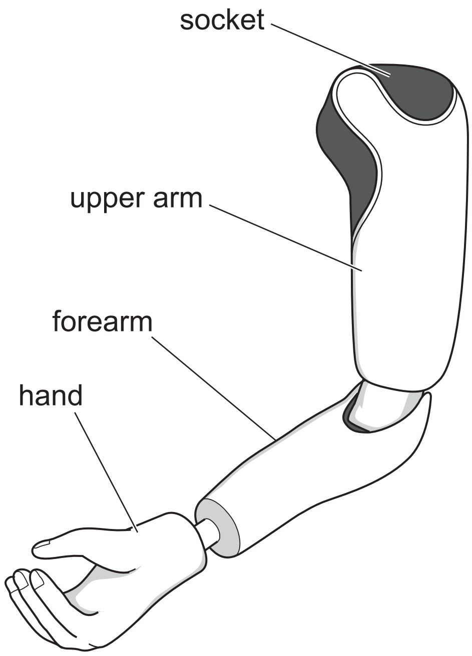

Fig. 3 A trial design for a 3D-printed prosthetic arm

3D-Printed Prosthetic Arm Specification

Fig. 4 shows dimensions of the 3D-printed prosthetic arm in mm. The elbow is a loose joint which is held at a fixed 90° by a tie attached between the upper arm and the forearm.

Fig. 5 is a force diagram for the prosthetic arm, showing the following forces:

L – load held by the hand

W – weight of the lower arm

F – tensile force in the tie

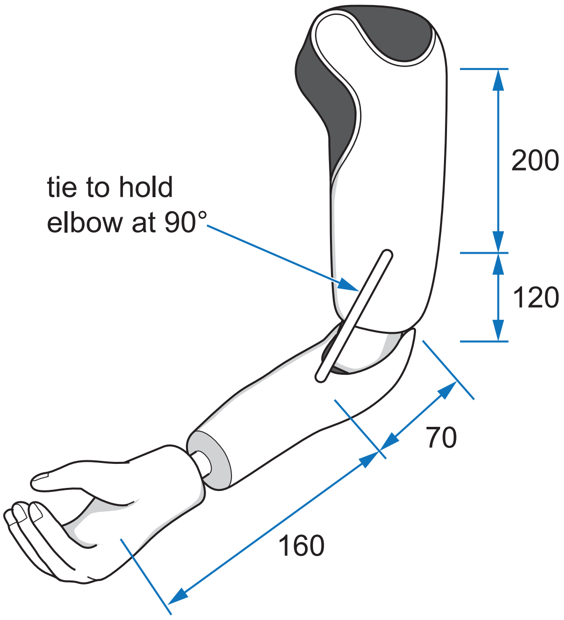

Fig. 4 Design sketch of 3D-printed prosthetic arm

(not to scale)

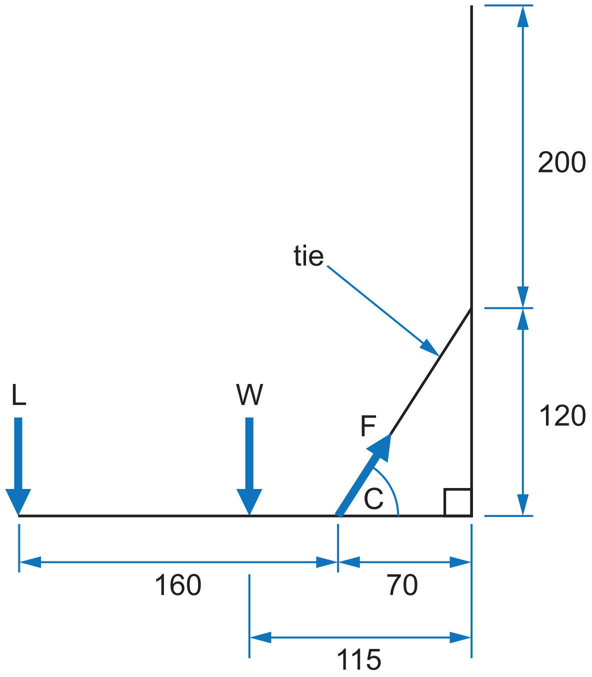

Fig. 5 Force diagram for the 3D-printed prosthetic arm

(not to scale)

Product Feature	Technical information
Type of prosthetic	Endoskeletal
Mass of lower arm	2 kg
Maximum recommended load which can be held in hand	9 kg
Socket material	Thermoplastic polyurethane

Fig. 6

Development of Robotic Surgery

Robot-assisted surgical procedures are becoming more commonplace in medical practice. In 1985 a robotic surgical arm was used for the first time in medical theatre to carry out an intricate medical procedure. In the 1990's, robotic-assisted surgical procedures, now including keyhole surgery, required approval and regulation by the Medicines and Healthcare Products Regulatory Agency (MHRA) of the United Kingdom.

Fig. 7 Surgical robot

More recently, more advanced technologies have been approved and regulated for general surgery such as the da Vinci Robotic Surgery System. This is an all-encompassing system that includes a range of surgical instruments and cameras thus reducing the number of surgical assistants performing general surgery.

The da Vinci system's three-dimensional magnification screen allows the surgeon to view the operative area with the clarity of high resolution. The one-centimetre diameter surgical arms represent a significant advancement in robotic surgery from the earlier, large-armed systems. With such miniaturised operating arms, this system removes the need to make large openings in the patient for the equipment to work. This advancement allows for less contact between exposed interior tissue and the surgical device.

Because robotic surgery is at the cutting edge of precision and miniaturisation in surgical procedures this minimises the need for more invasive surgery and as a consequence improves the recovery time of patients. Robotic surgery has already become a successful option in many different surgical areas ranging from operations of the brain to the heart and numerous other general surgical procedures. There are many engineers and surgeons collaborating to unlock the future potential of this technology as they invent better ways of accomplishing delicate medical procedures.

Endo-wrist

The Endo-wrist is a robotic system used to control the instruments during surgery. It is designed to replicate the movement of the surgeon's fingers. The slightest movement on the control unit will trigger a reaction at the tip of the instrument.

Fig. 8 The control unit which the surgeon would use to control the instrument

The surgeon's movements would be replicated by the chosen surgical instrument selected via a series of linear actuators and mechanisms designed to convert the motion of the linear actuator into a usable motion for the instrument. For example, the pinching of the surgeon's fore finger and thumb on the control unit would cause the jaws of the forceps shown in **Fig. 10** to close depending on the amount of movement input.

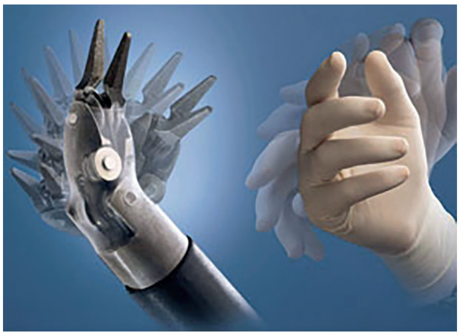

Fig. 9 The Endo-wrist is designed to replicate the movement of the surgeon's fingers

The forceps shown in **Fig. 10** open and close in an oscillating motion and they are used to hold or clamp objects during surgery.

The opening and closing motion is driven by a linear actuator which produces a linear motion similar to a pneumatic cylinder. The actuator produces a stroke of 5 mm.

This type of instrument is for one off usage and would be disposed of after an operation.

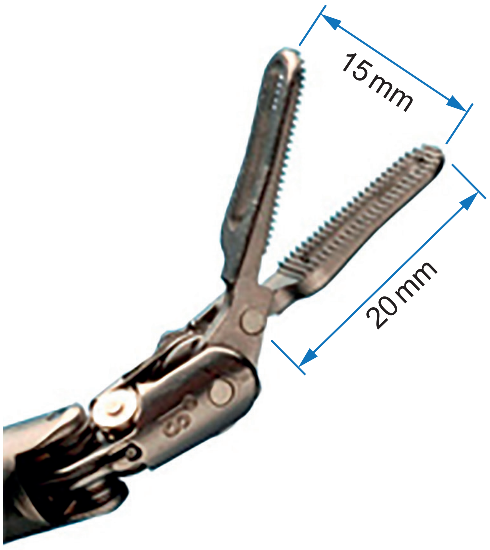

Fig. 10 A forceps tip, shown fully open

(not to scale)

BLANK PAGE