OCR
Oxford Cambridge and RSA

Tuesday 10 June 2025 – Morning

A Level in Design and Technology: Design Engineering

H404/02 Problem Solving in Design Engineering

Resource Booklet

Time allowed: 1 hour 45 minutes

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INSTRUCTIONS
- Use this Resource Booklet to answer **all** the questions.
- You should spend **35 minutes** reading this Resource Booklet.
- Do **not** send this Resource Booklet for marking. Keep it in the centre or recycle it.

INFORMATION
- This document has **12** pages.

ADVICE
- Read this Resource Booklet carefully **before** you start your answers.

The stimulus in this booklet relates to issues and opportunities that may be encountered when developing and deploying equipment used in disaster relief.

Technology Used in Disaster Relief

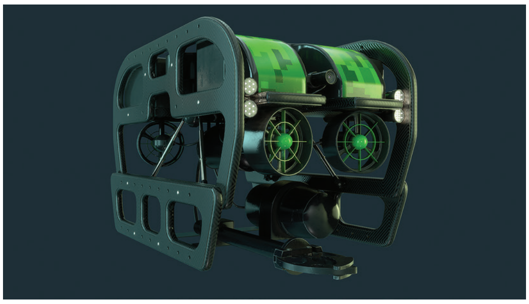
Communities can face significant danger from earthquakes, floods, wildfires and other natural disasters. During and after disasters, emergency workers rely on equipment to tackle the disaster directly and to help in the search and rescue of victims. Often victims need help after becoming trapped in building fires, crashes or after becoming stranded in mountainous terrain.

The Development of Rescue Vehicles

In the 1970s, early rescue equipment primarily consisted of manual tools and basic mechanical devices. Remote controlled systems began to appear, but they were often confined to simple vehicles connected to a control cable. Radio-controlled vehicles were developed but most struggled with the strength and reliability of the signal.

The 1990s saw more advanced robotic systems equipped with cameras and sensors. These were developed to access hazardous environments such as collapsed buildings or mines to aid in locating and rescuing trapped individuals. During this time, autonomous vehicles such as Autonomous Underwater Vehicles (AUVs) also began to be developed – see **Fig. 1**.

Fig. 1



These vehicles began to be used for search and rescue missions, being equipped with sonar and cameras to scan underwater environments. They were designed to operate in the cold and high pressure of the deep oceans where communicating with the vehicle is a huge challenge.

During the 2000s Unmanned Aerial Vehicles (UAVs) or ‘drones’ have become increasingly sophisticated. They can carry high resolution cameras and thermal imaging sensors and can be quickly deployed for aerial search and rescue. This allows a large search area to be covered in a short period of time. Already these systems have saved multiple lives by finding lost or isolated casualties quickly and they will continue to do so as the systems develop even further.

Fire-Fighting Robot

The Magirus Aircore TAF35 (see **Fig. 2**) is a remote-controlled fire-fighting robot. It is designed to assist firefighters in extinguishing fires, particularly fires spread over a large area such as wildfires. The robot is designed to run ahead and reach the source of the fire without risking the lives of firefighters. It has a wireless remote-control range up to 300 m.

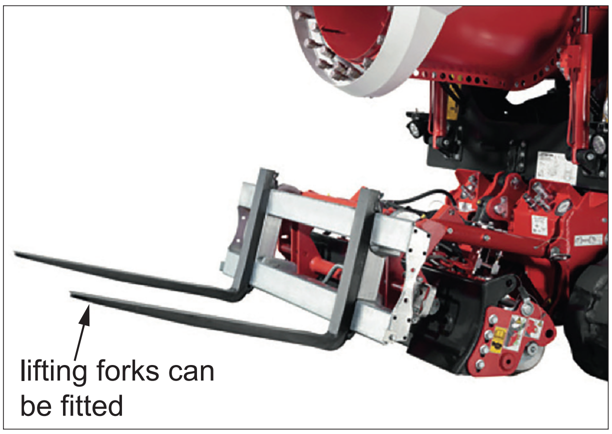
The robot can be fitted with cameras and thermal imagers. A variety of tools can also be attached, for example, lifting forks to move debris or to transport vulnerable materials away from the fire. It can pull loads up to 3.8 tonnes.

The Aircore concept uses a powerful air turbine to create a water mist which effectively cools the fire with minimum water usage. The jet can be projected up to 80 m. It also clears smoke, improving visibility for fighting the fire. The TAF35 is powered by a diesel engine which provides drive to the rubber tracks and provides power to the turbine. It can operate autonomously for up to seven hours.

Fig. 2

Magirus Aircore TAF35 Fire-fighting Robot:

Features:
- Liftable and tiltable water turbine.
- Turbine emits 4700 l/min water at 16 bar pressure.
- Throws water up to 80 m.



The Emergence of Artificial Intelligence (AI)

AI and machine learning technologies are being integrated into rescue equipment to enhance autonomy and decision-making capabilities. These systems use powerful AI algorithms to analyse the data collected by sensors and cameras. They can identify likely casualties and spot patterns worthy of further investigation. AI can prioritise search areas and maximise the search efficiency in time critical situations.

The integration of autonomous vehicles into rescue operations marks a significant technological advancement. It also raises a number of ethical considerations and concerns over safety and reliability. The ethical dilemma relies on the trust that society must place in these systems. Research by a charity indicated that of the people questioned globally only 27% feel safe with autonomous systems. This would mean that these systems would have to include robust fail-safes to mitigate risk.

Another ethical issue involves the decision-making algorithms that control autonomous vehicles. These dictate how to prioritise actions such as who to rescue first in multi-victim scenarios. Ensuring fairness, transparency and accountability is crucial to addressing these concerns.

The Scout Search Robot

The 'Scout' is a proposed design for a miniature search robot. It will be used during disaster relief to search in small, confined areas that the larger robots will struggle to access. It will be equipped with a tilting-fork mechanism which can help to clear small pieces of debris from its path. **Fig. 3** shows the initial concept design.

Fig. 3

Scout Specification

Dimensions of body	500 x 350 mm
Weight	10 kg
Speed	3.5 km/h

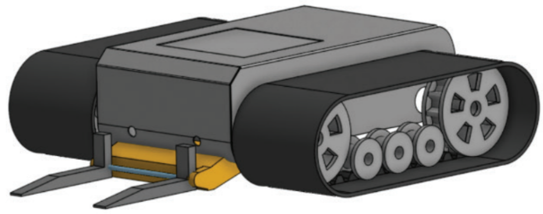
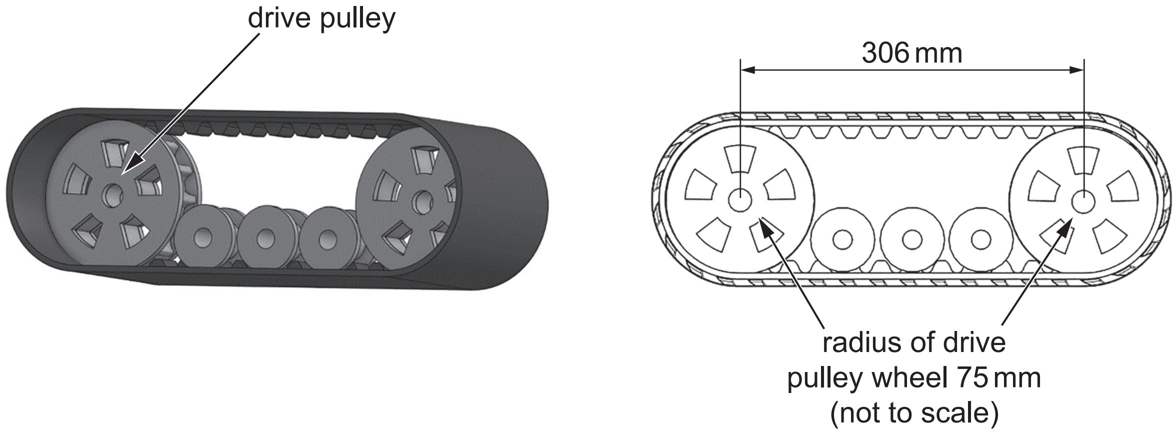


Fig. 4

The Scout Rubber Track Drive System:

The rubber tracks are a continuous belt driven by two pulleys.

The rubber track is made from a high-tech rubber which has a **density of 1100 kg / m^3** and a **cross-sectional area of 0.0015 m^2**.



SS-55 Electric Motor

Fig. 5

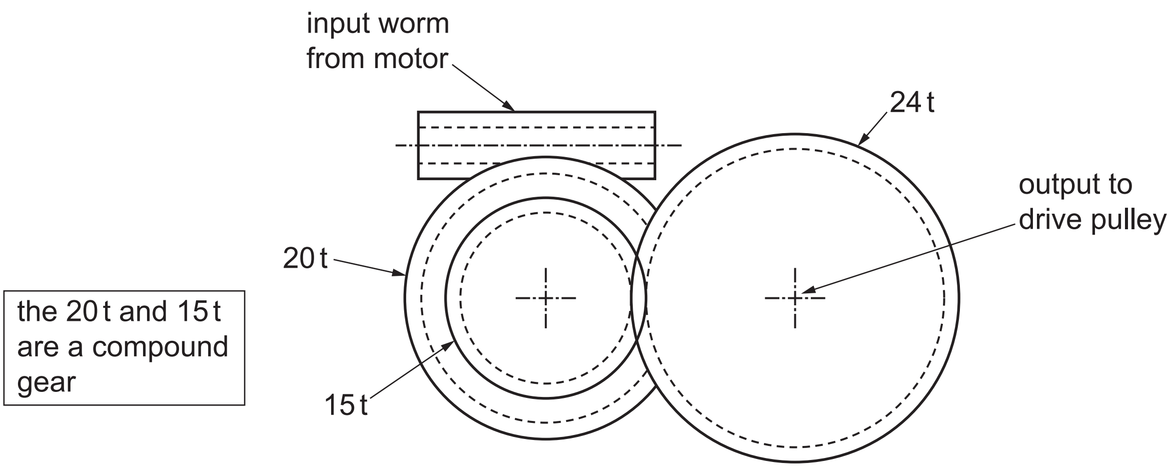
Specification

Supply voltage	12 v
DC Motor type	Brushless
Output speed	4000 rpm
Output torque	0.2 Nm

ZS-50 Gear Box

The ZS-50 gear box is used to reduce the speed of the motor and increase the torque to the rubber track drive pulley. The gear box consists of a worm drive on the input followed by a simple gear train. **Fig. 6** shows a schematic diagram of the gear box with the number of teeth on each gear.

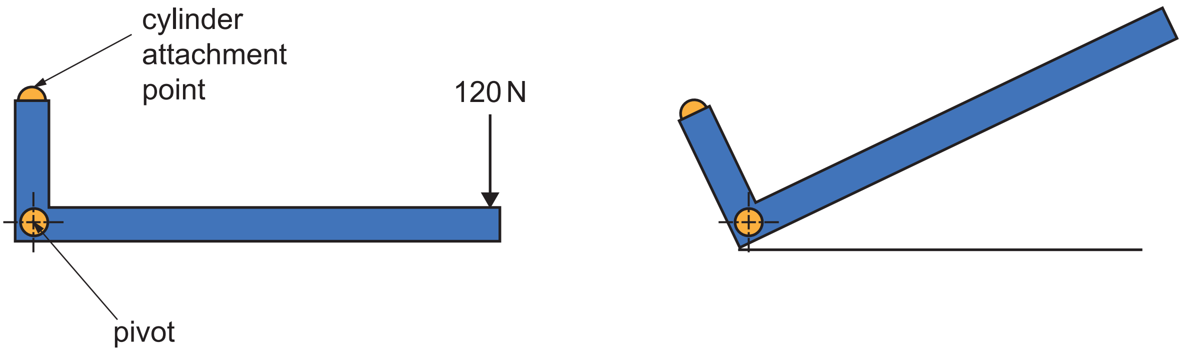
Fig. 6



Tilting Fork Mechanism

The Scout robot is equipped with a tilting fork mechanism which can be used to clear small pieces of debris from the robot's path. When activated, the fork will tilt up as shown in **Fig. 7**.

Fig. 7



The fork is not drawn to scale. The length from effort and load is still to be determined.

The movement will be achieved using a pneumatic cylinder which will be attached to the forks at the point shown in **Fig. 7**.

Fig. 8 shows the type of pneumatic cylinder that will be used and some accompanying data.

Fig. 8

System air pressure (max)	200 kPa
Cylinder diameter	0.016 m
Piston surface area	0.000201 m^2

The force exerted from a pneumatic cylinder can be calculated using the formula:

$F = PA$

Where:

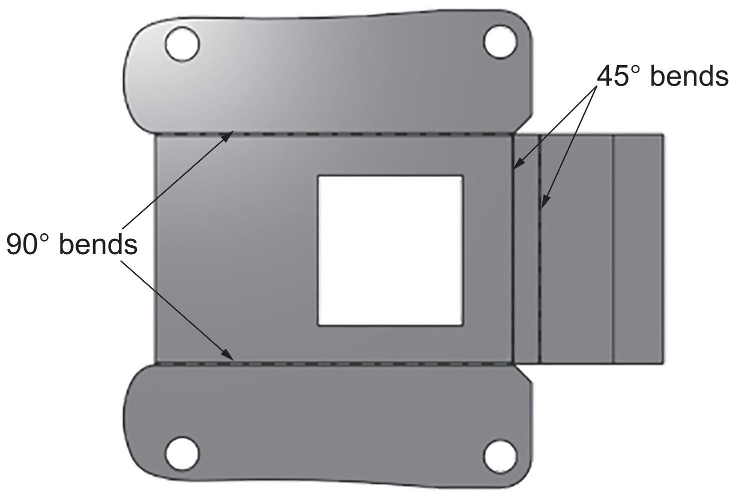
F = force (in N)
P = system air pressure (in Pa)
A = surface area of piston (in m^2)

The Scout Robot Chassis

The chassis is made of two parts which include a top casing shown in **Fig. 9** and a lower casing shown in **Fig. 10**. Both parts are manufactured from 3 mm thick aluminium sheet.

Fig. 9 – Top Casing with Access Hole:

Net of Top Casing



(not to scale)

Top Casing After Folding

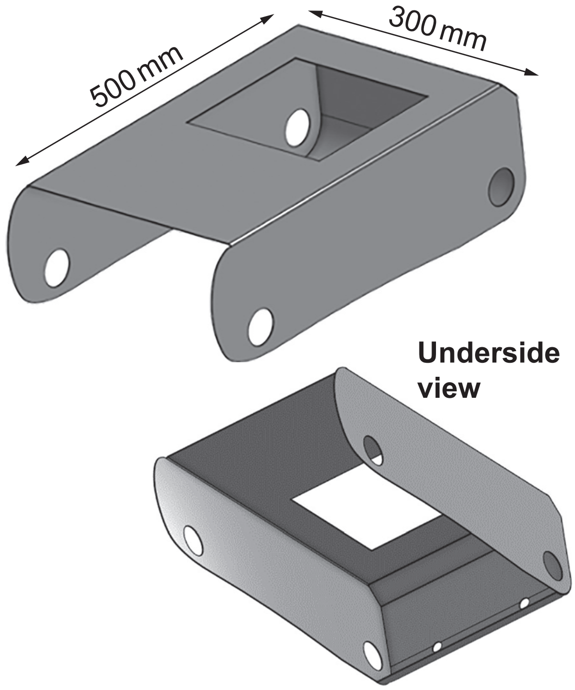
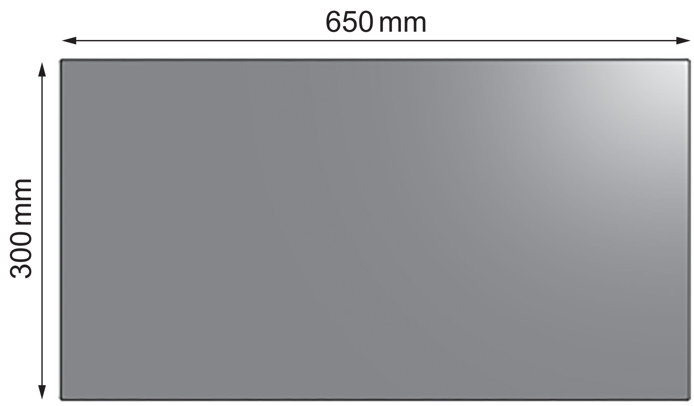


Fig. 10 – Lower casing:

Net of Lower Casing



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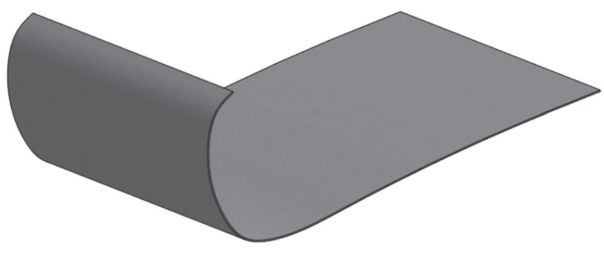
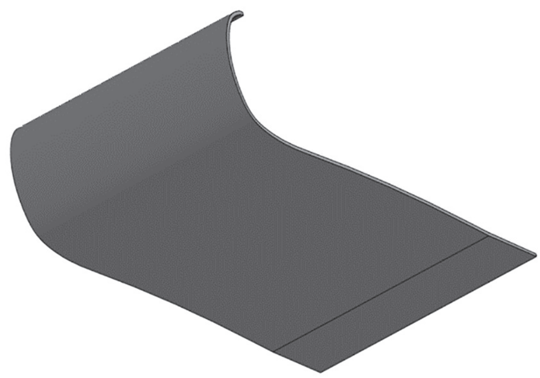
Lower Casing After Shaping



View of lower casing from underneath



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