OCR
Oxford Cambridge and RSA

Friday 16 June 2023 – Morning

A Level in Design and Technology: Design Engineering

H404/02 Problem Solving in Design Engineering

Resource Booklet

Time allowed: 1 hour 45 minutes

6889601022

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 by the impact of climate change.

Climate Change

Climate change refers to long-term changes in temperatures and weather patterns. Some of these changes occur naturally. However, human activities have also contributed to climate change through the burning of fossil fuels like coal, oil and gas as more energy is needed to power technological development.

Burning fossil fuels generates carbon dioxide, a greenhouse gas that acts like a blanket wrapped around the Earth. It traps the sun's heat and raises temperatures. As a result, the earth is now 1.1 °C warmer than it was in the late 1800's and the last decade was the warmest on record.

It is important to understand that the greenhouse effect is critical to life on earth. Without it, the temperature would be bitterly cold. However, by adding extra greenhouse gases into the atmosphere, humans have created an enhanced greenhouse effect. Instead of keeping the Earth at a stable temperature the planet is heating up.

Many people think climate change means warmer temperatures and longer summers. However, because the Earth consists of several interconnected systems, any change to one system will have an impact on the others. The consequences of a global temperature rise can include droughts and water shortages, wildfires, storms, melting polar ice, rising sea levels, flooding and a declining biodiversity. Many of these issues are being reported in the news.

Fig. 1

Climate change affects people around the world in many ways. Droughts and floods force whole communities to relocate and affect our ability to produce food, leading to famine and increasing food costs.

In 2022, the Environment Agency warned that severe flooding would become more common in certain regions of the UK because of the increasing number of intense storms. Of the 17 record breaking rainfalls since 1910, nine were recorded after the year 2000. A spokesman at the Environment Agency said 'Climate change is likely to mean more frequent and intense flooding. Floods impact lives, livelihoods and property.'

It is already too late to prevent climate change from happening. If the world acts now to reduce greenhouse gas emissions, then the devastating impacts that climate change could have on our lives can be reduced.

Agriculture, Forestry and Other Land Use (AFOLU)

24% of human-made greenhouse gas emissions comes from AFOLU. This is shown in **Fig. 2** alongside other sources of human-made greenhouse gas emissions.

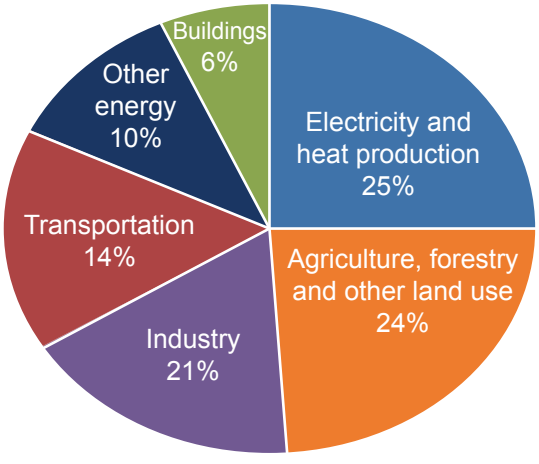


Fig. 2

Large areas of forests have been cleared to grow crops to feed people. Forests efficiently remove carbon dioxide from the atmosphere so cutting down trees allows carbon dioxide to build up even more. Land is also cleared to rear livestock for meat and milk. These animals produce large quantities of methane from their digestive process which is a greenhouse gas.

Fig. 3

11% of the world's greenhouse gas emissions comes from the methane released from decaying food waste which is dumped in landfill sites. If this food waste was composted it would break down by aerobic digestion. This produces far less methane. Composting also generates heat which on an industrial scale can be used as a renewable energy source. The resulting nutrient-rich compost is then put back on the land to feed new crops. This results in a circular food economy.

17% of global electronic waste was collected and recycled in 2019. The remainder became e-waste, much of which was burned or buried. This action has contributed further to greenhouse gas emissions.

A Global Responsibility

The emissions that cause climate change come from every part of the world and affect everyone. However, some countries produce much more than others.

- The 100 least-emitting countries generate 3% of total emissions.
- The 10 countries with the largest emissions contribute 68%.

Smaller island countries which contribute hardly any greenhouse gases have the most to lose as rising sea levels cause various challenges for these remote communities.

Action against climate change is expensive for governments and businesses. However, the costs of not taking action will be much higher in the years ahead. One important way forward is for the richer countries to help the developing countries prepare for the effects of climate change.

Education plays an important part as consumer trends need to change. People who understand the climate crisis are more likely to want to make the big changes (and personal sacrifices) needed to their lifestyle to help limit climate change.

Data Collection

An environmental charity, Weather Watch (WW), wishes to study the local impact of climate change by collecting weather data. The charity has been awarded funding to develop and distribute a weather monitoring station.

WW commissions a team of design engineers to develop a weather monitoring station that will be distributed to 100 000 households across the country to collect weather data.

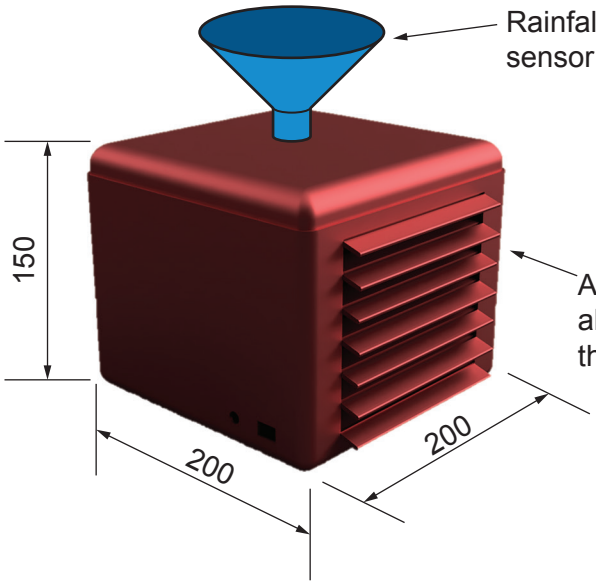
Once installed, the weather station will monitor the local weather conditions and upload the data to the charity's website. A remote display will be provided so that the weather data can be viewed inside the home.

The Pro Weather Station (PWS)

The design engineers have proposed a concept design for PWS which includes a sensor unit and remote display unit shown in **Fig. 4**.

All dimensions shown are in mm.

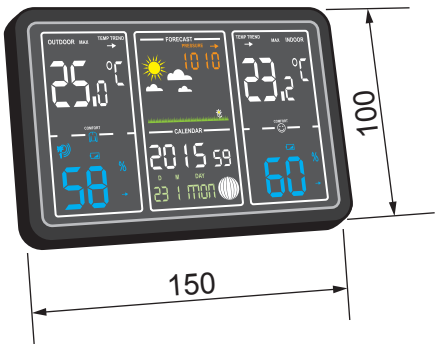
PWS sensor unit:



Weather monitoring includes:

- rainfall
- air temperature
- air humidity
- air pressure.

PWS remote display unit:



Function:

- enables weather data to be read remotely inside the home.

Fig. 4
(not to scale)

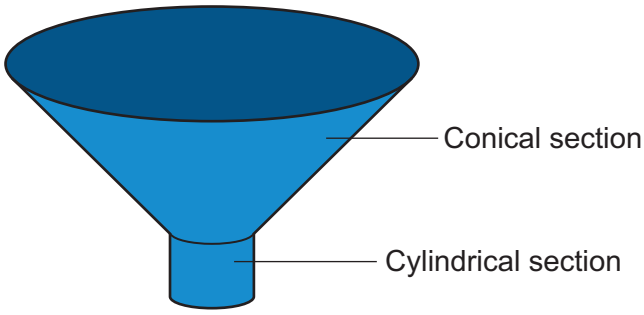
Rain Sensor

The funnel on the top of the PWS sensor unit catches rainwater for measurement.

The funnel consists of a conical section mounted above a cylindrical section as shown in **Fig. 5**.

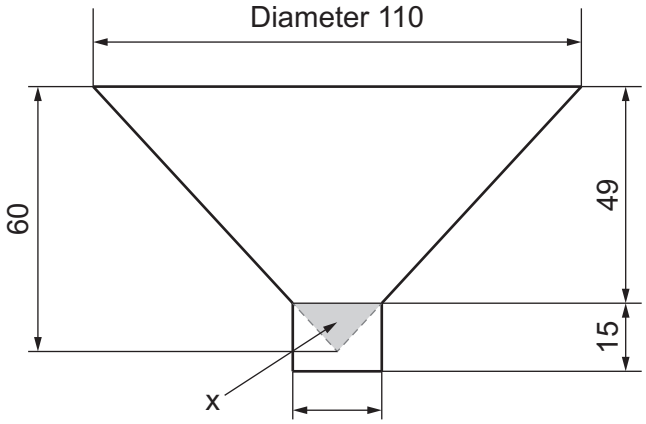
All dimensions shown are in mm.

Funnel:



- The volume of just the cylindrical section of the funnel is 4.7 cm^3.
- The volume of x is 1.15 cm^3.

Side view – internal dimensions of funnel:



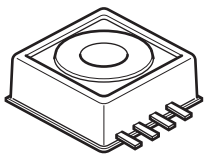
(not to scale)

Fig. 5

BP135 Pressure Sensor

The PWS uses the BP135 pressure sensor shown in **Fig. 6** to measure the air pressure.

BP135 pressure sensor:



Supply voltage	5.0 V
Supply current	8 mA
Output sensitivity	40 mV / kPa
Operating temperature range	–35 °C to +125 °C
Dimensions	7 × 7 × 2.8 mm

The BP135 pressure sensor produces an analogue output voltage which increases with air pressure.
The characteristic output voltage for the BP135 pressure sensor is shown in the graph.

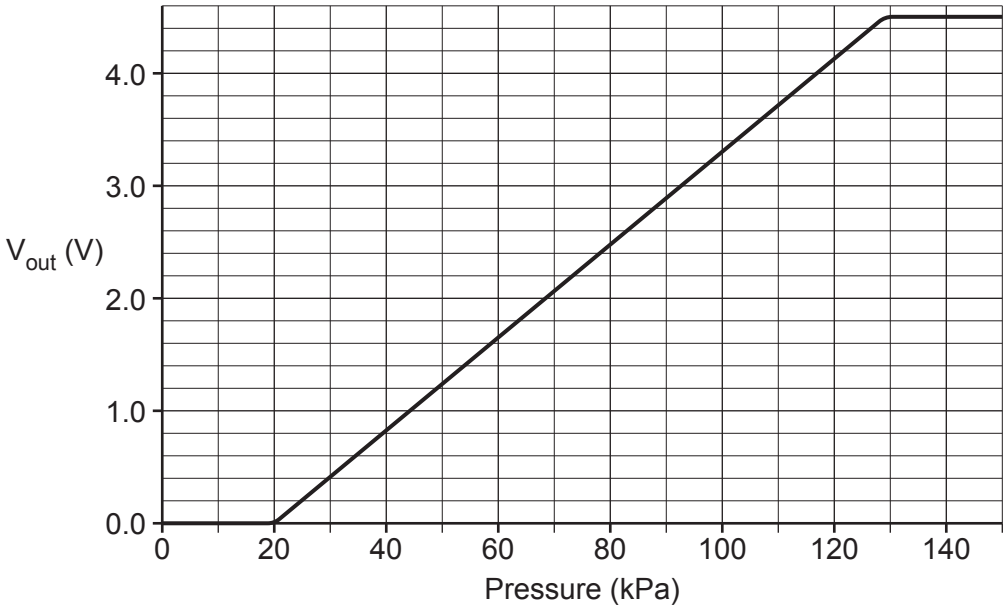


Fig. 6

Mounting the PWS Sensor Unit:

WW wishes to provide homeowners with a method of mounting the PWS sensor unit. Initial research undertaken by the design engineers indicates that weather stations should be mounted above the ground and away from buildings and trees.

The design engineers investigate different methods for mounting weather stations. The most typical methods found were the use of a monopole or a tripod as shown in **Fig. 7**.

A monopole is a mast that is made of only one pole.

Weather stations:

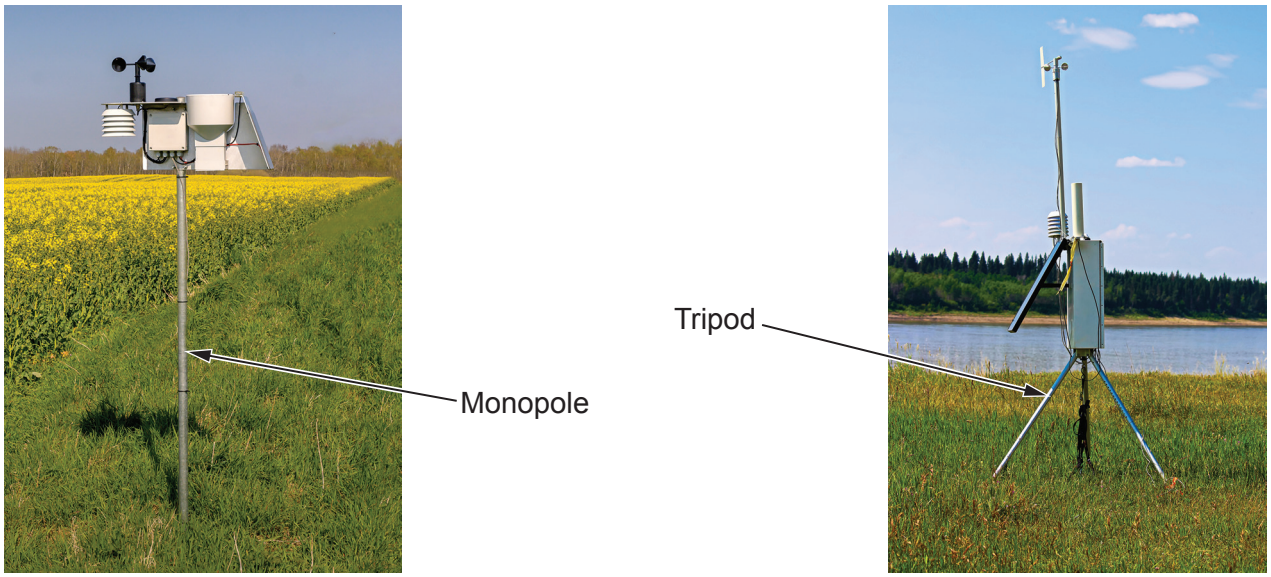


Fig. 7

Design Requirements

WW decides that in order to keep costs down the mounting solution should be based on a monopole and shipped to households as a set of parts, ready for assembly by the user.

The following design requirements have been agreed:

- the sensor unit must be mounted 3.0 m above the ground
- the dismantled stand will be flatpacked for transportation in a 1.5 m long cardboard tube
- the stand must be assembled **without** the use of tools
- the stand must be free-standing and stable in high winds
- the life expectancy must exceed 5 years.

Mild steel tubes:

Design engineers have decided that the monopole section of the mounting solution will be constructed using mild steel tubes. A range of suitable mild steel tubes has been identified below:

	External tube diameter (mm)	Internal tube diameter (mm)	Weight of 1.5 m long tube (kg)	Price for 1.5 m length (£)
Tube A	25.4	22.2	1.43	6.60
Tube B	28.6	25.4	1.63	8.00
Tube C	31.8	28.6	1.82	9.00
Tube D	34.9	31.8	2.01	10.20
Tube E	38.1	34.9	2.20	10.50

Fig. 8

Wind Speed Sensor

WW secures more funding to develop its product further. It wishes to explore the feasibility of adding a wind speed sensor to the PWS.

The design engineers are developing the wind speed sensor concept design shown in **Fig. 9**.

Wind speed sensor:

- Four cups are attached to horizontal arms. The arms are attached to a vertical rod.
- As the wind blows, the cups rotate making the rod spin. The faster the wind blows, the faster the rod spins.
- The number of rotations of the rod can be used to calculate wind speed.
- The rod spins in the base which will be attached to the PWS.

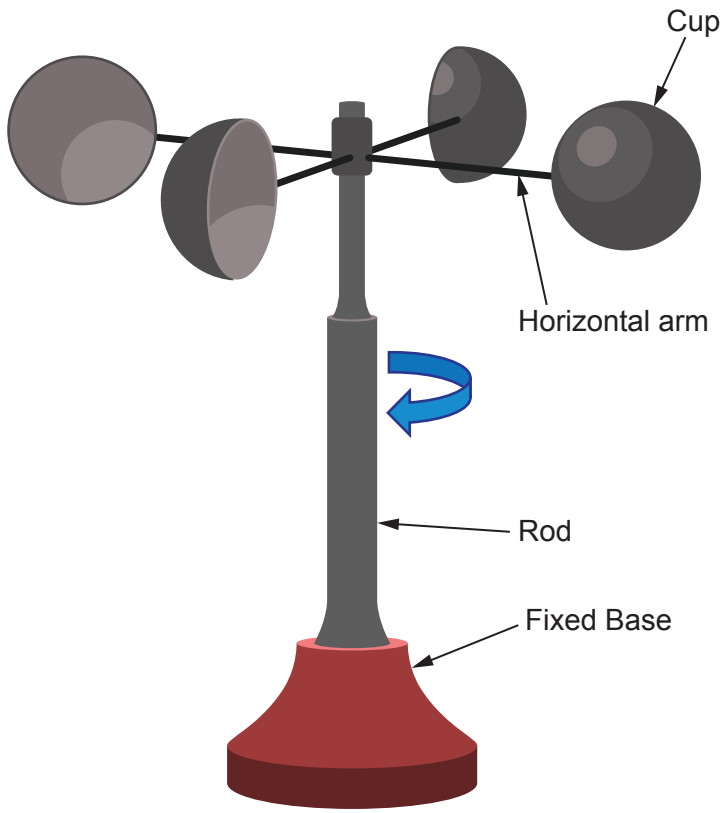


Fig. 9

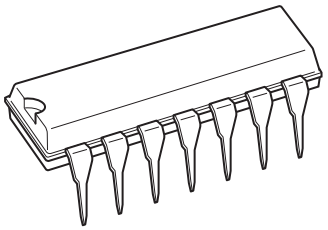
Electronic System

The design engineers need to develop the existing PWS electronic system to add the wind speed sensor.

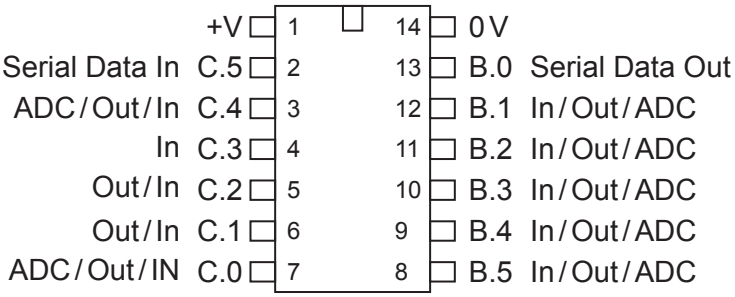
The PWS uses a PICAXE 14M2 microcontroller to process sensor signals. Data is transmitted to the remote display unit using a radio transmission circuit comprising an NKM2401 module connected to an A434 RF radio transmitter.

These components and corresponding circuit symbols are shown in **Fig. 10** and **Fig. 11**.

PICAXE 14M2 microcontroller:



Pinout diagram:



Features:

- 11 configurable input or output pins
- 7 analogue to digital conversion (ADC) pins
- serial data in and out.

Circuit symbol:

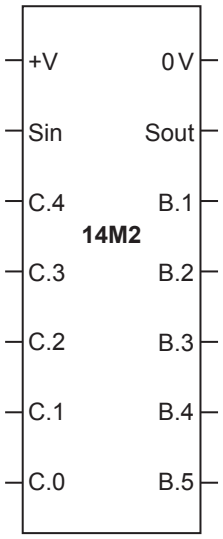
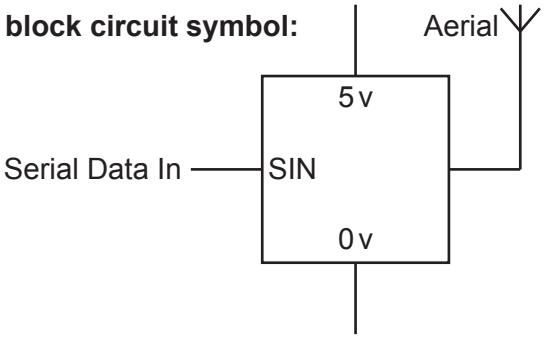


Fig. 10

Radio transmission circuit:

Simplified block circuit symbol:



Features:

- 10 kΩ pull-down resistor
- 100 nF noise filtering capacitors.

Exploded circuit diagram:

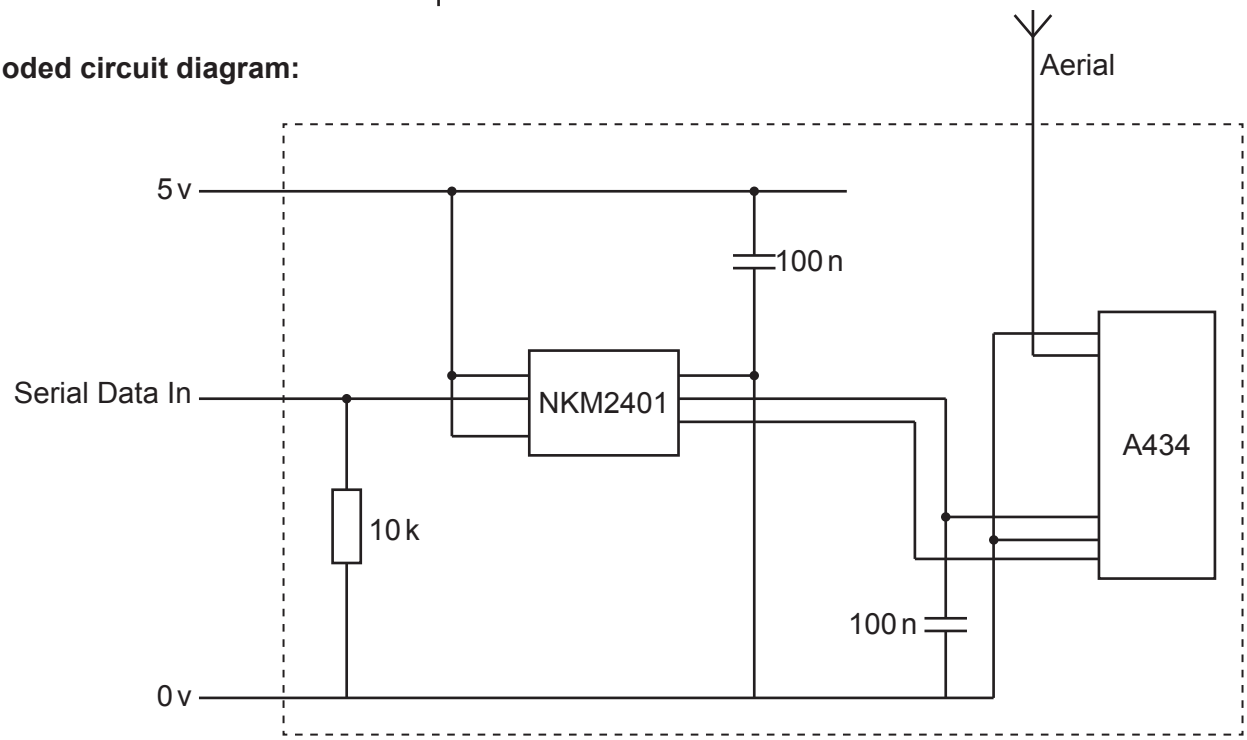


Fig. 11

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