Name: ______________________________ Teacher: ________________________

N5 Engineering Science
1 – Contexts and Systems

Success Criteria		R	A	G
1. Engineering and Engineers				
1.1	I can describe what engineering is and explain how engineers solve real-world problems.			
1.2	I can identify different branches of engineering, including civil, structural, mechanical, electrical, electronic, chemical and environmental engineering.			
1.3	I can describe the role of different engineers in the design, building, testing and control of engineered systems.			
1.4	I can explain how different types of engineers work together on the same project.			
1.5	I can use correct engineering terminology when describing what engineers do.			
1.6	I can identify problems, needs, users, contexts and constraints in an engineering situation.			
2. Engineering Contexts and Impacts				
2.1	I can identify the problem or need that an engineering project is trying to solve.			
2.2	I can describe positive and negative **social** impacts of an engineering solution.			
2.3	I can describe positive and negative **economic** impacts of an engineering solution.			
2.4	I can describe positive and negative **environmental** impacts of an engineering solution.			
2.5	I can explain impacts using a clear **what + why** answer structure.			
3. Sustainability and Emerging Technologies				
3.1	I can describe how engineering solutions can help tackle climate change.			
3.2	I can explain what makes an engineering solution more sustainable.			
3.3	I can describe how emerging technologies can improve engineering solutions.			
3.4	I can give advantages and disadvantages of new engineering technologies.			

Success Criteria		R	A	G
4. The Systems Approach				
4.1	I can describe a system as a group of parts working together to perform a task.			
4.2	I can identify the **input**, **process** and **output** of an engineered system.			
4.3	I can draw and label a simple system diagram.			
4.4	I can identify sub-systems within a larger engineered system.			
4.5	I can draw sub-system diagrams using correctly labelled blocks and arrows.			
4.6	I can describe the function of each sub-system and how the sub-systems interact.			
4.7	I can identify input and output devices/transducers in a system.			
5. Control Systems				
5.1	I can describe what is meant by control in an engineered system.			
5.2	I can identify examples of manual and automatic control.			
5.3	I can describe the difference between open-loop and closed-loop control.			
5.4	I can identify a feedback loop in a closed-loop system.			
5.5	I can explain how feedback allows a system to monitor and adjust its output.			
5.6	I can draw and interpret open-loop and closed-loop control diagrams.			
5.7	I can explain set value, actual value, error and error detector in a closed-loop system.			

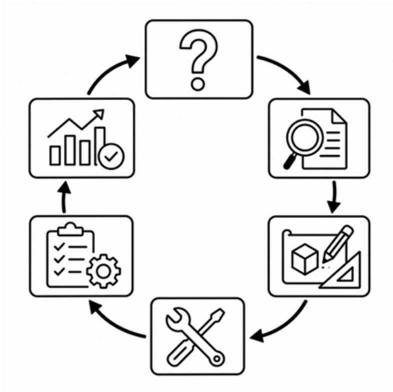
1. Engineering and Engineers

What is Engineering?

Engineering is the use of **science, mathematics, technology and creativity** to solve real-world problems.

Engineers do more than build things. They may:

Engineering action	Meaning
research	find out information about the problem, users and constraints
design	plan a possible solution
simulate	model or test an idea before building it fully
implement	put the design into action by building, wiring, programming or installing
test	check if the solution works correctly and safely
control	make a system behave in the required way
evaluate	judge how well the solution works and suggest improvements



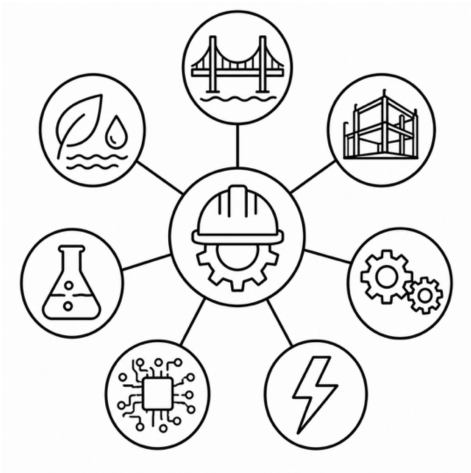
Task — Identify the Problem

Context	Engineering problem	Possible solution	One constraint
A cycle path is very dark after school in winter.			
A local town floods after heavy rain.			
A factory machine overheats after running for a long time.			
A farm needs to water crops automatically.			

Main Branches of Engineering

Different engineers specialise in different types of problems.

Branch of engineering	Main role
Civil engineering	Designs infrastructure such as roads, bridges, tunnels and flood defenses.
Structural engineering	Checks that structures can withstand forces and loads safely.
Mechanical engineering	Designs moving parts, machines and mechanical systems.
Electrical engineering	Works with electrical power, wiring, motors and large electrical systems.
Electronic engineering	Works with circuits, sensors, signals and control systems.
Chemical engineering	Works with materials, fuels and chemical processes.
Environmental engineering	Reduces environmental damage and improves sustainability.



Electrical or Electronic?

Electrical engineer	Electronic engineer
Works mainly with electrical power.	Works mainly with electronic signals and control.
May work on wiring, motors, lighting and power supplies.	May work on sensors, circuit boards and microcontrollers.
Example: power supply for a factory.	Example: light sensor circuit for automatic lights.

Task — Match the Engineer

Job	Branch of engineering
Checks whether a building can support heavy loads safely.	
Designs a gear system inside a machine.	
Designs the power supply and wiring for a school building.	
Designs a sensor circuit to control automatic doors.	
Develops a rust-resistant coating for outdoor metal parts.	
Designs a drainage system to reduce flood risk.	

Engineers Working on a Project

Example — Automatic School Door System

Engineer	What they might do	Why this matters
Mechanical engineer	Design the moving parts of the door.	The door must open smoothly and safely.
Electrical engineer	Plan the power supply and wiring.	The system must receive electrical energy safely.
Electronic engineer	Design the sensor and control circuit.	The door must detect a person and open automatically.

Example — Flood Defense Scheme

Engineer	What they might do	Why this matters
Civil engineer	Plan the layout of the flood defenses and drainage.	The scheme must protect the town from flooding.
Structural engineer	Check that walls, barriers or supports can withstand water forces.	The defenses must stay strong and stable.
Environmental engineer	Consider effects on rivers, habitats and pollution.	The scheme should reduce environmental damage.

Task — One Project, Many Engineers

Choose one project.

wind turbine, electric bus system, railway bridge, recycling plant

hydroelectric power station, hospital building

Project chosen: ____

Engineer	What would they do?	Why does this matter?
1.		
2.		
3.		

Section 1 Practice

1. State what engineering is.

2. A company is designing a sensor circuit that switches on a warning light when a machine overheats. Identify the most suitable type of engineer for this task.

3. Describe the role of a structural engineer in a bridge project.

4. Explain why engineers need to test a design before it is used.

5. A council is planning new flood defences for a town. Explain how two different types of engineers could be involved in the project.

6. Explain why engineers must consider constraints when designing a solution.

2. Engineering Contexts and Impacts

Engineering Contexts

Examples

Context	Problem or need	Possible engineering solution
A town floods after heavy rain.	Homes, roads and businesses can be damaged by flood water.	Flood defences, drainage systems and river monitoring.
A school wants to reduce wasted energy.	Lights and heating may be left on when rooms are empty.	Automatic lighting and heating control systems.
A rural area has poor transport links.	People may find it difficult to travel to work, school or shops.	Improved bus routes, electric buses or better roads.

Task — Identify the Context

Complete the table.

Context	Problem or need	Possible engineering solution
A bridge is too weak for modern traffic.		
A factory uses too much electrical energy.		
A village has poor mobile phone signal.		
A school entrance is difficult for wheelchair users.		
A farm needs to water crops during dry weather.		

Social, Economic and Environmental Impacts

Engineering solutions can have different types of impact.

Type of impact	Meaning
social impact	how people, communities, health, safety or quality of life are affected
economic impact	how money, jobs, businesses, costs or local services are affected
environmental impact	how nature, resources, pollution, energy use or waste are affected

An impact can be **positive** or **negative**.

Impact type	Positive example	Negative example
Social	A new bridge makes travel safer and easier.	Construction noise may disturb local residents.
Economic	A new factory may create jobs.	The project may be expensive to build.
Environmental	A wind turbine can reduce fossil fuel use.	It may affect wildlife or the appearance of the landscape.

Task — Identify Impacts

For each engineering solution, write one **positive** and one **negative** impact.

Engineering solution	Impact type	Positive impact	Negative impact
New flood defenses	Social		
Wind farm	Environmental		
Energy-efficient equipment	Economic		
Electric buses	Social or environmental		
New road bridge	Social or economic		

Section 2 Practice

1. State what is meant by an engineering context.

2. A town has traffic congestion and poor air quality. Identify one engineering solution that could help with this problem.

3. Describe one positive social impact of installing automatic doors at a school entrance.

4. Describe one negative economic impact of building a new road bridge.

5. Explain one positive environmental impact of using electric buses instead of diesel buses.

6. A company installs energy-efficient motors in a factory. Explain one positive economic impact of this engineering solution.

7. A wind farm is built near a village. Explain one positive and one negative impact of this engineering solution.

3. Sustainability and Emerging Technologies

Engineering and Climate Change

Engineering solutions can help reduce the causes and impacts of climate change.

Task — Engineering and Climate Change

Engineering solution	How could it help tackle climate change?
Wind turbine	
Solar-powered street lights	
Automatic lighting in a school	
Improved insulation in homes	
Recycling plant	

Sustainable Engineering Solutions

Task — Make It More Sustainable

Design	Problem	More sustainable improvement
A school heating system stays on when rooms are empty.	Energy is wasted.	
A phone case is made from non-recyclable plastic.	More plastic waste is produced.	
A town uses diesel buses.	Exhaust emissions are produced.	
A product is cheap but breaks after a few weeks.	More waste is produced.	

Emerging Technologies

An **emerging technology** is a new or developing technology that could change how engineering problems are solved.

Use a reliable source to research one emerging technology. Wikipedia may be used as a starting point, but you should also check another source such as a company, university, engineering organisation or news article.

Emerging technology:	
What problem could it help solve?	
Social impact	
Economic impact	
Environmental impact	
One advantage	
One disadvantage	

Section 3 Practice

1. State what is meant by a sustainable engineering solution.

2. Identify one engineering solution that could help tackle climate change.

3. Describe one way engineers can reduce wasted energy in a building.

4. Describe one emerging technology that could be used in engineering.

5. Explain why using renewable energy can make an engineering solution more sustainable.

6. A factory replaces old motors with more efficient motors. Explain one positive environmental impact of this engineering solution.

7. A council installs smart sensors in a flood defence system. Explain how this emerging technology could improve the engineering solution.

8. A town is considering replacing diesel buses with electric buses. Give one advantage and one disadvantage of this engineering solution.

4. The Systems Approach

What is a System?

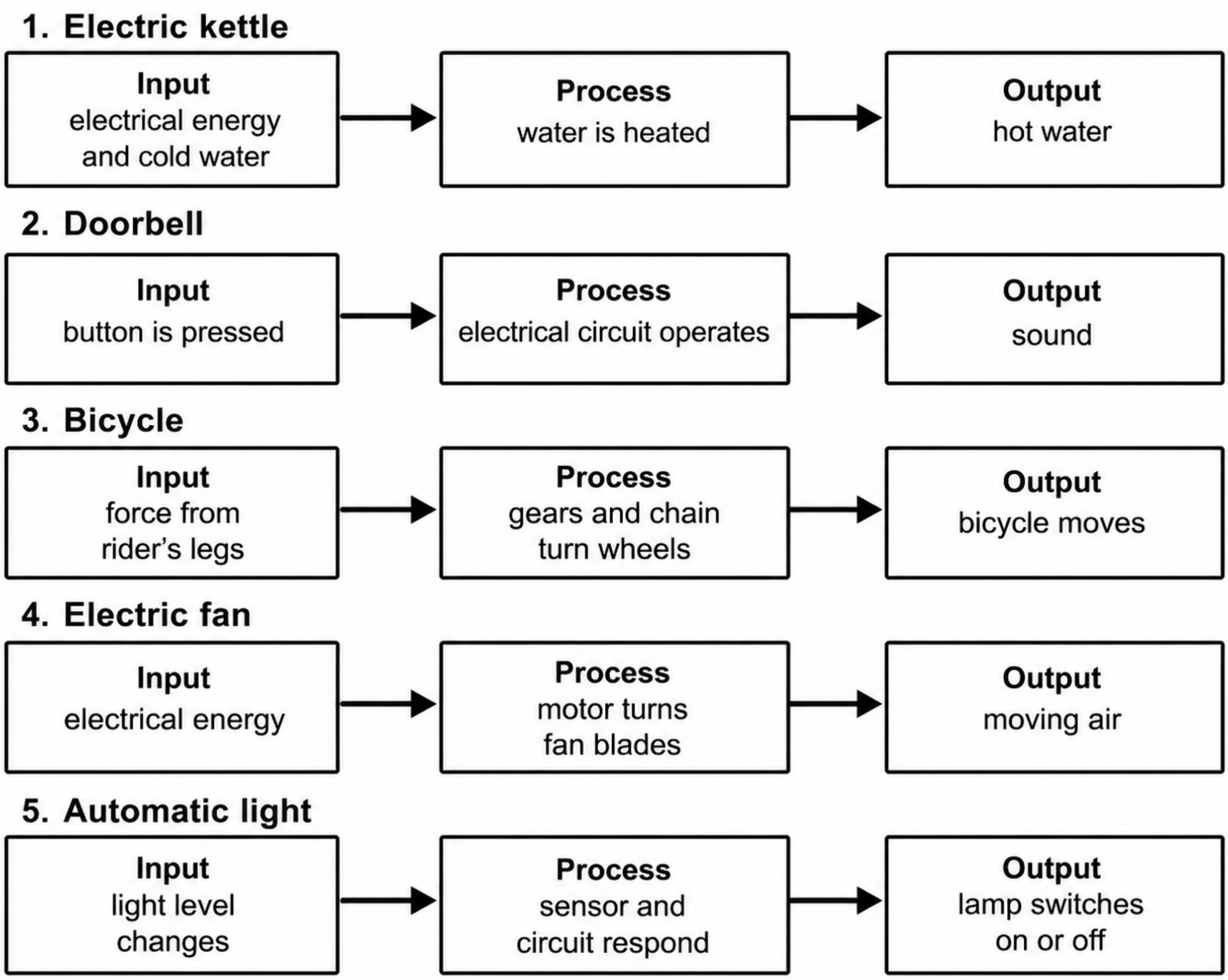
A **system** is a group of parts working together to carry out a task.

Engineers use the **systems approach** to break a product, machine or process into smaller parts. This makes it easier to understand, design, test and improve.

Input → Process → Output

Word	Meaning
system	a group of parts working together to carry out a task
input	what goes into a system
process	what the system does to the input
output	what comes out of a system
sub-system	a smaller part of a larger system
system boundary	a line showing what is included inside the system being studied

Examples



Task — Input and Output Devices

Complete the table.

Situation	Suitable input device	Suitable output device
A light turns on when it gets dark.		
A warning buzzer sounds when a door opens.		
A fan turns on when a room gets too hot.		
An automatic door opens when a person approaches.		
A heater switches on when water is too cold.		

Task — Describe the System

For each system, draw a systems diagram

1. Traffic lights

2. School bell

3. Electric toothbrush

Sub-systems

A **sub-system** is a smaller part of a larger system.

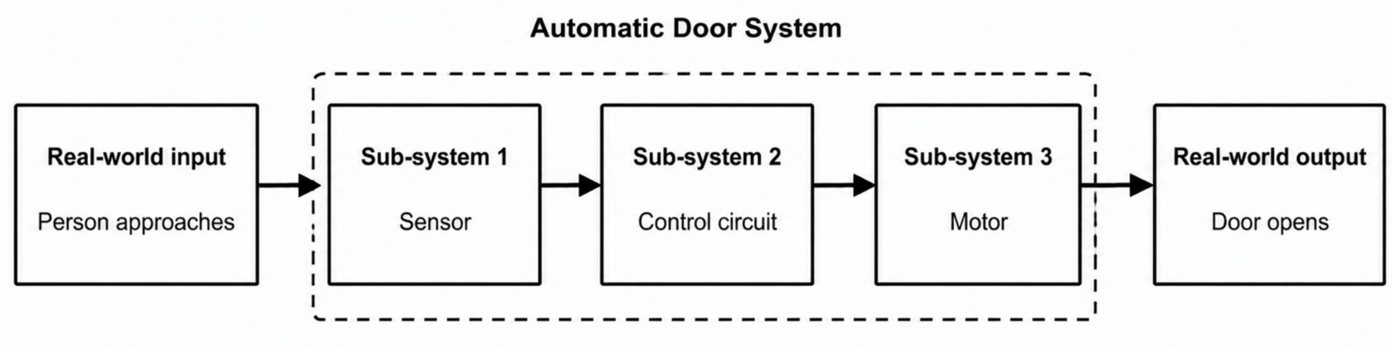
Sub-systems interact when the **output from one sub-system becomes the input to another**.

This means that one part of the system affects another part.

Example — Automatic Door System

Sub-system	Function
Sensor sub-system	detects a person near the door
Control sub-system	processes the signal from the sensor
Motor sub-system	opens or closes the door
Door mechanism	moves the door safely

The sensor sends a signal to the control sub-system. The control sub-system switches on the motor. The motor moves the door mechanism so that the door opens.



Task — Draw a Sub-system Diagram

Draw a sub-system diagram for one of the systems below.

Choose one:

washing machine, wind turbine, school heating system

Section 4 Practice

1. State what is meant by a system.

2. Identify the input, process and output for an electric kettle.

3. Describe the operation of a doorbell using the systems approach.

4. Explain why engineers use system diagrams.

5. State what is meant by a sub-system.

6. Describe two sub-systems found in a washing machine.

7. Explain how sub-systems interact in an automatic door system.

8. Draw a labelled sub-system diagram for an automatic door system.

9. Describe the difference between a real-world input and an input device.

10. Describe the difference between an output device and a real-world output.

5. Control Systems

What is Control?

A **control system** makes a system operate in the required way.

Control systems are used in engineered products, machines and processes. They help systems operate safely, reliably and efficiently.

A control system may:

- switch something on or off;
- keep something at a set level;
- control movement;
- control temperature;
- control speed;
- respond to a sensor;
- stop a system becoming unsafe.

Word	Meaning
control system	the part of a system that controls how it works
manual control	control carried out by a person
automatic control	control carried out by technology, sensors or electronics
set value	the value the system is trying to reach or maintain
actual value	the real value being measured by the system
feedback	information sent back to the control system about the output
error	the difference between the set value and the actual value
error detector	the part of the system that compares the set value and actual value

Examples

System	What is being controlled?
Central heating	Room temperature
Washing machine	Water level, temperature and drum movement
Automatic door	Door movement
Oven	Cooking temperature
Street light	When the lamp switches on or off
Electric fan	Air movement

Task — What is Being Controlled?

Complete the table.

System	What is being controlled?
Electric oven	
Fire Alarm	
School bell system	

Manual and Automatic Control

Manual control

- a person switches a light on;
- a person turns a tap off when a bath is full;
- a person presses a button to open a door.

Automatic control

- a thermostat switches heating on and off;
- a motion sensor switches a light on;
- a washing machine controls the wash cycle;
- an automatic door opens when a person is detected.

Task — Manual or Automatic?

For each example, decide whether the system uses manual control or automatic control.

Example	Manual or automatic?
A person switches on a classroom light.	
A thermostat switches heating on when a room is cold.	
A driver presses the brake pedal in a car.	
A motion sensor opens a door.	
A timer switches a school bell on.	
A person turns a tap off when a sink is full.	

Open-loop Control

An open-loop control system produces an output, but does not check or monitor the output.

The input causes the system to work, but the system does not use feedback to adjust itself.

Simple open-loop diagram

Input → control system → output device → output

Task — Open-loop Control

System	Input	Output	Why is it open-loop?
Light switch			
Hairdryer			
Toaster			
Electric fan with on/off switch			

Feedback

Feedback is information sent back to the control system about the output.

Feedback allows the system to check whether the output is correct.

Feedback is used in closed-loop control systems.

Example — Central Heating

Part	Description
Set value	The temperature selected on the thermostat
Actual value	The real room temperature
Sensor	Temperature sensor in the thermostat
Feedback	Signal showing the actual room temperature
Response	Heating switches on or off

If the room is too cold, the heating switches on.

If the room reaches the set temperature, the heating switches off.

Task — Feedback

For each system, identify the feedback.

System	What feedback is sent back to the control system?
Central heating system	
Oven	
Automatic water tank	
Automatic door with a safety or position sensor	
Electric car battery management system	

Closed-loop Control

A **closed-loop control system** monitors the output and uses feedback to adjust the system.

The system compares the **actual value** with the **set value**. If there is a difference, the system makes a change.

Closed-loop system	How feedback is used
Central heating	A thermostat monitors room temperature and switches heating on or off.
Oven	A temperature sensor monitors the oven temperature and adjusts the heater.
Automatic bath filling system	A level sensor detects when the water reaches the correct level.
Cruise control in a car	The system monitors speed and adjusts engine power.

Error Detection

An **error detector** compares the set value with the actual value.

If the values are different, there is an **error**.

The control system then acts to reduce the error.

Example — Room Heating

Part	Example
Set value	20 °C
Actual value	16 °C
Error	The room is 4 °C too cold
Control action	Heating switches on

When the actual temperature reaches the set value, the heating can switch off.

Task — Error Detection

Complete the table.

Situation	Set value	Actual value	Error	Control action
Oven temperature	180 °C	160 °C		
Water tank level	Full line	Below full line		

Task — Draw Control Diagrams

Draw a control diagram for each system.

1. Open-loop system — Hairdryer

2. Closed-loop system — Central Heating

Section 5 Practice

1. State what is meant by a control system.

2. Identify one example of manual control.

3. Identify one example of automatic control.

4. State what is meant by open-loop control.

5. State what is meant by closed-loop control.

6. Describe the difference between open-loop and closed-loop control.

7. A room heater is controlled using a thermostat. Explain why this is an example of closed-loop control.

8. A toaster heats bread for a fixed time and does not check the colour of the toast. Explain why this is an example of open-loop control.

9. Describe the operation of a central heating system using the following words: **set value** **thermostat** **feedback** **control system** **heating**

10. Draw a labelled closed-loop control diagram for a central heating system.

Knowledge Organiser

Key Definitions

Word	Meaning
engineering	using science, maths, technology and creativity to solve real-world problems
context	the situation an engineering problem belongs to
constraint	a limit on the design (cost, time, weight, safety, materials)
fit for purpose	the design works correctly, safely and meets the user's needs
social impact	effect on people, communities and quality of life
economic impact	effect on money, jobs, businesses and costs
environmental impact	effect on nature, resources, pollution and energy use
sustainable	meets needs today without harming the future
system	a group of parts working together to carry out a task
sub-system	a smaller part of a larger system
input device	part that takes a real-world signal into a system
output device	part that produces a real-world action from a system
open-loop control	output not monitored, no feedback
closed-loop control	output monitored, feedback adjusts the system
feedback	information sent back about the output
set value	the value the system is trying to maintain
actual value	the real measured value
error	difference between set value and actual value
error detector	the part that compares set value and actual value

Branches of Engineering — Quick Reference

Branch	Mainly works on
Civil	infrastructure (roads, bridges, drainage)
Structural	strength and stability of structures
Mechanical	machines, mechanisms and moving parts
Electrical	power, wiring and large electrical systems
Electronic	circuits, sensors and signals
Chemical	materials, fuels and chemical processes
Environmental	reducing damage and improving sustainability

Open-loop vs Closed-loop

Open-loop	Closed-loop
No feedback	Uses feedback
Output not monitored	Output monitored by a sensor
Cannot self-correct	Adjusts to reduce error
Examples: light switch, toaster, hairdryer	Examples: central heating, oven, cruise control

Common Mistakes

Watch out for these in your answers

- Confusing electrical and electronic engineering. Power = electrical; signals/sensors = electronic.
- Saying a system is "automatic" when a person is doing the controlling.
- Drawing a system diagram without arrows showing direction of flow.
- Forgetting feedback or the error detector in a closed-loop diagram.
- Listing only positive impacts (or only negative) — a balanced answer covers both.
- Writing "good" or "bad" instead of social, economic or environmental.
- Forgetting the what + why structure on explain questions.
- Mixing up an input device (e.g. switch, sensor) with the input it detects (e.g. someone pressing it).