Name: ________________________ Teacher: ______________________

N5 Engineering Science
2 – Energy and Efficiency

Success Criteria	R	A	G
1. Forms of Energy			
1.1 I can identify different forms of energy used in engineering.			
1.2 I can describe energy transfers in engineering systems.			
1.3 I can apply the law of conservation of energy.			
1.4 I can identify useful and wasted energy in a system.			
2. Energy Calculations			
2.1 I can calculate work done using $E_w = F d$.			
2.2 I can calculate kinetic energy using $E_k = \frac{1}{2} m v^2$.			
2.3 I can calculate potential energy using $E_p = m g h$.			
2.4 I can calculate electrical energy using $E_e = V I t$.			
2.5 I can calculate heat energy using $E_h = c m \Delta T$.			
2.6 I can calculate power using $P = E / t$.			
2.7 I can rearrange formulae to find an unknown quantity.			
2.8 I can use correct units and convert between them where required.			
3. Efficiency and Energy Audits			
3.1 I can describe how energy is wasted in a system.			
3.2 I can complete an energy audit diagram.			
3.3 I can calculate efficiency as a ratio ($\eta = E_{out} / E_{in}$).			
3.4 I can calculate percentage efficiency ($\eta = (E_{out} / E_{in}) \times 100$).			
3.5 I can apply efficiency calculations to engineering contexts.			
3.6 I can use efficiency information to compare engineering solutions.			

1. Forms of Energy

Energy can exist in many different forms. Engineers must be able to recognise the most common ones.

Form of energy	Meaning	Example
kinetic energy	the energy of a moving object	moving vehicle
potential energy	the energy stored when an object is raised up	raised lift cage
electrical energy	the energy carried by an electric current	current in a motor
heat (thermal) energy	the energy a hot object has	hot water in a tank
chemical energy	the energy stored in fuels and batteries	petrol, battery
light energy	the energy carried by light	lamp, LED
sound energy	the energy carried by sound waves	buzzer, speaker

Focus for National 5 Calculations

At National 5, the four forms used in calculations are:

- kinetic energy (Ek)
- potential energy (Ep)
- electrical energy (Ee)
- heat energy (Eh)

TASK — Match the Energy Form

Example	Form of energy
A car driving along a road.	
A book held high above the floor.	
Current flowing through a heater element.	
A hot mug of tea.	
Petrol in a fuel tank.	
Light shining from an LED.	
A buzzer sounding in a circuit.	

2. Energy in Engineering Systems

Why Energy Matters

Engineers use energy to make systems work. Almost every engineered product moves something, heats something, lights something or sends a signal. All of these need energy.

Energy can take many different forms. Engineers must understand:

- what energy is going into a system
- what useful energy comes out
- how much energy is wasted

Engineers try to design systems that waste as little energy as possible. This saves money, saves resources and reduces harm to the environment.

Key Words

Word	Meaning
energy	the ability to do work or cause change
input energy	the total energy supplied to a system
useful output energy	the energy that does the job the system was designed for
wasted energy	energy that is transferred to forms or places we do not want
efficiency	a measure of how much input energy becomes useful output energy

TASK — Identify Input, Useful and Wasted Energy

System	Input	Useful output	One form of wasted energy
Electric kettle	electrical	heat (in water)	heat (in kettle and air), sound
Electric heater			
Electric motor			
Battery torch			
Filament light bulb			
Petrol car engine			
Hairdryer			

3. Energy Transfers and the Law of Conservation of Energy

Energy cannot be created. Energy cannot be destroyed. Energy can only be transferred from one place to another or transformed from one form to another.

This means that the total energy in a system always stays the same. If you add up all the useful energy and all the wasted energy, you get back the same amount as the input energy.

Block Diagrams

Engineers use simple block diagrams to show how energy changes form in a system.

Example — Electric Kettle

electrical energy → heat energy in water → heat energy lost to surroundings

Example — Wind Turbine

kinetic energy of wind → kinetic energy of blades → electrical energy

TASK — Energy Transfer Diagrams

Complete an energy transfer diagram for each system.

Electric motor	→	→	→
Generator	→	→	→
Battery-powered torch	→	→	→
Hairdryer	→	→	→

PRACTICE — Forms of Energy

1. State the law of conservation of energy. (1)

2. Name three forms of energy used in engineering. (3)

3. Identify the useful output energy from an electric kettle. (1)

4. Identify one form of wasted energy from an electric motor. (1)

5. A hairdryer takes in electrical energy. Describe two forms of energy that come out. (2)

6. A wind turbine produces electrical energy. State the input energy and one form of wasted energy. (2)

7. Describe what is meant by useful output energy. (1)

8. Explain why no real system gives out only useful energy. (2)

9. A battery torch produces light. State the energy change from the battery to the light. (2)

10. Describe one reason why engineers try to reduce wasted energy in a system. (2)

4. Work Done

Work is done when a force moves an object through a distance. The energy used to do this work is called work done.

$$Ew = F\,d$$

Symbol	Quantity	Unit
E_w	work done	joules (J)
F	force	newtons (N)
d	distance moved	metres (m)

Worked Example

A factory worker pushes a trolley with a force of 80 N for 12 m. Calculate the work done.

$$Ew = F\,d$$

$$Ew = 80 \times 12$$

$$Ew = 960\,J$$

TRY THIS — Work Done

1. A worker lifts a box using a force of 150 N. The box is lifted 1.2 m. Calculate the work done. (3)

2. A crane pulls a steel beam horizontally with a force of 4500 N for 8 m. Calculate the work done. (3)

3. A robot arm exerts a force of 12 N to move a component 0.5 m along a conveyor. Calculate the work done. (3)

5. Kinetic Energy

Kinetic energy is the energy a moving object has. The faster and heavier the object is, the more kinetic energy it has.

$$\boldsymbol{Ek = ½\, m\, v^2}$$

Symbol	Quantity	Unit
Ek	kinetic energy	joules (J)
m	mass	kilograms (kg)
v	speed	metres per second (m/s)

Worked Example

A car has a mass of 1200 kg and is travelling at 15 m/s. Calculate the kinetic energy.

$$Ek = ½\, m\, v^2$$

$$Ek = ½ \times 1200 \times 15^2$$

$$Ek = 135\,000\, J$$

TRY THIS — Kinetic Energy

1. A trolley of mass 4 kg is moving at 3 m/s. Calculate its kinetic energy. (3)

2. A robot of mass 20 kg moves along a factory floor at 2 m/s. Calculate the kinetic energy. (3)

3. A van has a mass of 2500 kg and travels at 18 m/s. Calculate the kinetic energy. (3)

6. Potential Energy

Potential energy is the energy stored in an object because of its height above the ground. The higher and heavier an object is, the more potential energy it has. Use g = 9.8 N/kg unless the question gives a different value.

$$Ep = m\,g\,h$$

Symbol	Quantity	Unit
Ep	potential energy	joules (J)
m	mass	kilograms (kg)
g	grav. field strength	9.8 N/kg
h	height	metres (m)

Worked Example

A lift cage of mass 600 kg is raised 8 m up a lift shaft. Calculate the gain in potential energy.

$$Ep = m\,g\,h$$

$$Ep = 600 \times 9.8 \times 8$$

$$Ep = 47\,040\,J$$

TRY THIS — Potential Energy

1. A crane lifts a load of mass 250 kg to a height of 5 m. Calculate the gain in potential energy. (3)

2. A box of mass 12 kg is placed on a shelf 2.5 m above the ground. Calculate the potential energy gained. (3)

3. Water of mass 5000 kg is held behind a dam at a height of 40 m. Calculate the potential energy stored. (3)

7. Electrical Energy

Electrical energy is the energy delivered by an electric current. The energy supplied depends on the voltage, the current and the time. Always convert time to seconds before substituting.

$$\boldsymbol{Ee = V\,I\,t}$$

Symbol	Quantity	Unit
Ee	electrical energy	joules (J)
V	voltage	volts (V)
I	current	amperes (A)
t	time	seconds (s)

Worked Example

A motor runs at 12 V drawing a current of 3 A for 5 minutes. Calculate the electrical energy supplied.

$$t = 5 \times 60 = 300\,s$$

$$Ee = V\,I\,t$$

$$Ee = 12 \times 3 \times 300$$

$$Ee = 10\,800\,J$$

TRY THIS — Electrical Energy

1. A heater runs at 230 V drawing a current of 8 A for 2 minutes. Calculate the electrical energy supplied. (3)

2. A pump operates at 24 V and draws 2 A for 10 minutes. Calculate the electrical energy used. (3)

3. A charger supplies 5 V at 2 A for 1 hour. Calculate the electrical energy delivered. Give your answer in kJ. (4)

8. Heat Energy

Heat energy is the energy needed to change the temperature of a material. It depends on the mass, the temperature change and the specific heat capacity of the material. Use c = 4180 J/kg˚C for water unless the question gives a different value.

$$Eh = c\,m\,\Delta T$$

Symbol	Quantity	Unit
Eh	heat energy	joules (J)
c	specific heat capacity	J/kg˚C
m	mass	kilograms (kg)
ΔT	temperature change	˚C

Worked Example

A kettle heats 0.5 kg of water from 20 ˚C to 100 ˚C. Calculate the heat energy needed.

$$\Delta T = 100 - 20 = 80\,°C$$

$$Eh = c\,m\,\Delta T$$

$$Eh = 4180 \times 0.5 \times 80$$

$$Eh = 167\,200\,J$$

TRY THIS — Heat Energy

1. A heating element warms 2 kg of water from 15 ˚C to 65 ˚C. Use c = 4180 J/kg˚C. Calculate the heat energy needed. (3)

2. A factory water tank holds 80 kg of water. The water is heated from 12 ˚C to 60 ˚C. Calculate the heat energy required. (3)

3. A copper engine part of mass 0.4 kg is heated from 20 ˚C to 220 ˚C. The specific heat capacity of copper is 386 J/kg˚C. Calculate the heat energy required. (4)

9. Power

Power is the amount of energy transferred each second. A higher power means more energy is delivered in the same time. Rearrange to E = P × t or t = E / P as needed.

$$\boldsymbol{P = E / t}$$

Symbol	Quantity	Unit
P	power	watts (W)
E	energy	joules (J)
t	time	seconds (s)

Worked Example

A motor transfers 18 000 J of energy in 30 seconds. Calculate the power of the motor.

$$P = E / t$$

$$P = 18\,000 / 30$$

$$P = 600\,W$$

TRY THIS — Power

1. A heater transfers 96 000 J of energy in 2 minutes. Calculate the power. (3)

2. A pump has a power rating of 500 W. It runs for 5 minutes. Calculate the energy used. (3)

3. A motor is rated at 750 W and supplies 45 000 J of useful energy. Calculate how long it operated for. (3)

PRACTICE — Energy Equations

1. State the equation for work done. (1)

2. A pump pushes water along a pipe with a force of 220 N. The water moves 6 m. Calculate the work done. (3)

3. A conveyor belt does 750 J of work moving a box 2.5 m. Calculate the size of the force needed. (3)

4. A conveyor system carries a 30 kg box at 1.5 m/s. Calculate the kinetic energy. (3)

5. A delivery vehicle of mass 1800 kg travels at 12 m/s. Calculate the kinetic energy. (3)

6. A goods lift carries a 320 kg load up a height of 12 m. Calculate the gain in potential energy. (3)

7. An electric motor in a workshop runs at 240 V with a current of 5 A for 8 minutes. Calculate the electrical energy supplied. (4)

8. A heater is connected to a 230 V supply. It draws 6 A and is switched on for 15 minutes. Calculate the electrical energy used. Give your answer in kJ. (4)

9. An industrial heater warms 25 kg of water from 18 $^\circ$C to 80 $^\circ$C. Calculate the heat energy required. Use c = 4180 J/kg$^\circ$C. (4)

10. An aluminium component of mass 1.2 kg is heated by 90 $^\circ$C. The specific heat capacity of aluminium is 902 J/kg$^\circ$C. Calculate the heat energy needed. (3)

11. An electric motor transfers 24 000 J of energy in 40 s. Calculate the power. (3)

12. A 1.5 kW heater is switched on for 4 minutes. Calculate the energy supplied. Give your answer in kJ. (4)

10. Conservation of Energy

Energy cannot be created or destroyed. It can only be changed from one form to another, or transferred from one place to another.

In any real engineering system, some of the input energy becomes useful output energy. The rest is wasted, often as heat or sound.

$$\textit{input energy} = \textit{useful output energy} + \textit{wasted energy}$$

TASK — Account for the Energy

Calculate the wasted energy in each system.

System	Input energy (J)	Useful output (J)	Wasted energy (J)
Electric motor	1200	900	
Lift cage	5000	3800	
Light bulb	60	12	
Electric kettle	200 000	168 000	
Hairdryer	8000	1500	

11. Efficiency

Efficiency is a measure of how much input energy becomes useful output energy. A more efficient system wastes less energy. No real system is 100 % efficient.

Efficiency as a ratio

$$\boldsymbol{\eta = Eout\,/\,Ein}$$

Percentage efficiency

$$\boldsymbol{\eta = (Eout\,/\,Ein) \times 100}$$

Symbol	Quantity	Unit
η	efficiency	ratio or %
Eout	useful output energy	joules (J)
Ein	input energy	joules (J)

These formulas also work with power values: η = Pout / Pin.

Worked Example

An electric motor is supplied with 800 J of energy. It produces 600 J of useful kinetic energy. Calculate the percentage efficiency.

$$\eta = (Eout\,/\,Ein) \times 100$$

$$\eta = (600\,/\,800) \times 100$$

$$\eta = 75\,\%$$

TRY THIS — Efficiency

1. A heater uses 2400 J of electrical energy. Of this, 2160 J becomes useful heat. Calculate the percentage efficiency. (3)

2. A motor takes in 1000 W of power and gives out 850 W of useful mechanical power. Calculate the percentage efficiency. (3)

3. A wind turbine receives 12 kW of kinetic power from the wind and produces 4.8 kW of electrical power. Calculate the percentage efficiency. (3)

12. Energy Audits

An energy audit shows how the energy supplied to a system is used. It shows the total input energy, the useful output energy and the wasted energy.

Example 1 — Electric Kettle

200 000 J electrical → kettle → useful 168 000 J heat in water; wasted 32 000 J heat to surroundings.

Example 2 — Filament Light Bulb

60 J electrical → bulb → useful 6 J light; wasted 54 J heat.

TASK 5 — Complete the Audit

System	Input (J)	Useful (J)	Wasted (J)	Efficiency (%)
Hairdryer	8000	1500		
LED bulb	10	8		
Industrial heater	50 000		5000	
Crane motor	20 000		4000	
Pump	1500			60

13. Engineering Decision Task

Choosing a New Motor for a School Workshop

A school engineering workshop needs to replace an old motor used for a small lathe. Two motors are being considered. Use the data to help the school make a decision.

	Motor A	**Motor B**
Input power	1000 W	800 W
Useful output power	700 W	640 W
Cost	£120	£180
Expected lifetime	5 years	10 years

1. Calculate the percentage efficiency of Motor A. (3)

2. Calculate the percentage efficiency of Motor B. (3)

3. State which motor is more efficient. (1)

4. Describe one economic reason for choosing Motor B. (2)

5. Describe one environmental reason for choosing the more efficient motor. (2)

6. Recommend which motor the school should choose. Explain your answer using your calculations and at least one other reason. (3)

PRACTICE — Efficiency and Energy Audits

1. Describe what is meant by efficiency. (1)

2. Explain why no real engineering system can be 100 % efficient. (2)

3. Describe one reason why engineers carry out energy audits. (2)

4. A motor uses 1500 J of electrical energy. It produces 1050 J of useful kinetic energy. Calculate the percentage efficiency. (3)

5. A pump has an input power of 800 W and a useful output power of 560 W. Calculate the percentage efficiency. (3)

6. A lighting system uses 240 J of electrical energy. It is 25 % efficient. Calculate the useful light energy produced. (3)

7. An electric vehicle motor draws 100 A from a 320 V battery for 30 seconds during acceleration. Calculate the electrical energy supplied. (3)

8. Using the data from question 7: the motor is 80 % efficient. Calculate the useful kinetic energy produced. (3)

9. A goods lift in a factory raises a 500 kg load by 12 m. Calculate the gain in potential energy. (3)

10. The lift motor in question 9 uses 75 000 J of electrical energy. Calculate the percentage efficiency of the lift system. (3)

11. A small wind turbine receives 5000 W of kinetic power and produces 1750 W of electrical power. Calculate the percentage efficiency. (3)

12. Explain one reason why a wind turbine cannot be 100 % efficient. (1)

13. A motor uses 600 J of electrical energy. 200 J is wasted as heat and sound. Calculate the percentage efficiency. (3)

14. A factory uses an old electric motor that wastes a lot of energy as heat. Suggest one engineering change that would reduce the waste and explain how it works. (2)

End-of-Topic Self-Check

Confidence Checklist

Statement	☺️	–	☹️
I can recall the law of conservation of energy.			
I can identify input, useful output and wasted energy.			
I can use $E_w = F\,d$ correctly.			
I can use $E_k = \frac{1}{2}\,m\,v^2$ correctly.			
I can use $E_p = m\,g\,h$ correctly.			
I can use $E_e = V\,I\,t$ correctly.			
I can use $E_h = c\,m\,\Delta T$ correctly.			
I can use $P = E\,/\,t$ correctly.			
I can rearrange a formula to find an unknown.			
I can convert J / kJ / MJ and minutes / hours / seconds.			
I can complete an energy audit diagram.			
I can calculate efficiency as a ratio and as a percentage.			

Mixed Self-Check Questions

1. State the law of conservation of energy. (1)

2. A 6 kg robot moves at 2 m/s. Calculate its kinetic energy. (3)

3. A crane lifts an 80 kg crate by 5 m. Calculate the gain in potential energy. (3)

4. A heater operates at 230 V drawing 4 A for 1 minute. Calculate the electrical energy supplied. (4)

5. A 1500 W motor runs for 2 minutes. Calculate the energy used in kJ. (3)

6. A pump uses 4000 J of energy and produces 2800 J of useful output energy. Calculate the percentage efficiency. (3)

7. Explain why a real engineering system can never be 100 % efficient. (2)

8. An LED bulb uses 8 J of electrical energy. It is 70 % efficient. Calculate the useful light energy produced. (3)

9. A factory wants to reduce energy use. Describe one engineering action that would help and explain how it reduces energy waste. (2)

10. A motor uses 600 J of electrical energy. 200 J is wasted as heat and sound. Calculate the percentage efficiency. (3)

Notes Page

Knowledge Organiser

Key Definitions

Word	Meaning
energy	the ability to do work or cause change
work done	the energy used when a force moves an object
power	energy transferred per second
efficiency	a measure of useful output compared with total input
energy audit	a record of where input energy goes in a system
conservation of energy	energy cannot be created or destroyed, only changed in form

Formulae

Quantity	Formula	Units
Work done	$E_w = F\,d$	J, N, m
Kinetic energy	$E_k = \frac{1}{2} m v^2$	J, kg, m/s
Potential energy	$E_p = m\,g\,h$	J, kg, N/kg, m
Electrical energy	$E_e = V\,I\,t$	J, V, A, s
Heat energy	$E_h = c\,m\,\Delta T$	J, J/kg°C, kg, °C
Power	$P = E / t$	W, J, s
Efficiency (ratio)	$\eta = E_{out} / E_{in}$	(no unit)
Percentage efficiency	$\eta = (E_{out} / E_{in}) \times 100$	%

Common Conversions

From	To
1 kJ	1000 J
1 MJ	1 000 000 J
1 kW	1000 W
1 minute	60 s
1 hour	3600 s

Common Mistakes

- Forgetting to convert time into seconds before using a formula.
- Forgetting to square the speed in $E_k = \frac{1}{2} m v^2$.
- Forgetting to multiply by 100 when finding percentage efficiency.
- Using final temperature instead of ΔT in $E_h = c\,m\,\Delta T$.
- Mixing up input energy with useful output energy.
- Treating wasted energy as destroyed — it is still energy, just not useful.
- Mass in grams instead of kilograms.
- Mixing up energy (J) and power (W).