

AQA GCSE Physics

Energy

Teacher Booklet

Name: _____

Teacher: _____

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LESSON 1

Energy Stores & Gravitational Potential Energy

Do Now

1. What is the unit of energy?

Joule (J)

2. Name two types of energy store.

Any two of: kinetic, gravitational, elastic, thermal, chemical, nuclear, electrostatic, magnetic

3. What does "g" represent in physics equations?

Gravitational field strength (N/kg); on Earth $g = 9.8 \text{ N/kg}$

4. If an object is lifted higher, what happens to its gravitational potential energy?

It increases

Part 1 of 3: Energy Stores

Energy is the ability to do work. Whenever something happens anywhere in the universe, energy is transferred.	1
Energy is stored in objects. The main energy stores are: gravitational, kinetic, elastic, thermal, chemical, nuclear, electrostatic and magnetic .	2
Energy cannot be created or destroyed – it is only transferred between stores. This is the Law of Conservation of Energy .	3
The unit of energy is the Joule (J) . Larger quantities are expressed in kJ ($1 \text{ kJ} = 1000 \text{ J}$) or MJ.	4

Questions

1. Define energy.	(1)
2. Name four energy stores.	(2)
3. State the Law of Conservation of Energy.	(2)
4. A ball is held above the ground. Which energy store does it have?	(1)
5. Convert 4500 J into kJ.	(1)

Answers

1. *The ability to do work / capacity to cause change.*

2. *Any four from: gravitational, kinetic, elastic, thermal, chemical, nuclear, electrostatic, magnetic.*

3. *Energy cannot be created or destroyed, only transferred between stores.*

4. *Gravitational potential energy store.*

5. *4.5 kJ*

Part 2 of 3: Gravitational Potential Energy

Gravitational potential energy (GPE) is stored when an object with mass is raised in a gravitational field.	1
The formula for GPE is: $E_{GP} = m \times g \times h$	2
E_{GP} = gravitational potential energy store (J); m = mass (kg); g = gravitational field strength (N/kg); h = height above the ground (m).	3
On Earth, $g = 9.8 \text{ N/kg}$. GPE increases if mass, height, or g increases.	4
Example: A rock of mass 75 kg is lifted 4 m. $E_{GP} = 75 \times 9.8 \times 4 = \mathbf{2940 \text{ J}}$.	5

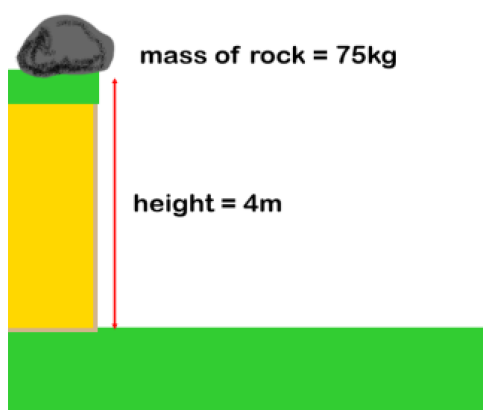


Fig 1.1 – A rock raised 4 m above the ground storing gravitational potential energy.

Questions

1. Define gravitational potential energy store.	(1)
2. What does g measure? Give its value on Earth.	(2)
3. A 5 kg book is placed on a shelf 1.5 m high. $g = 9.8 \text{ N/kg}$. Calculate its GPE.	(3)
4. If the height of an object doubles, what happens to its GPE? Explain.	(2)
5. A 60 kg person stands on a 3 m diving board. $g = 9.8 \text{ N/kg}$. Calculate GPE.	(3)

Answers

1. Energy stored due to an object's position in a gravitational field.
2. Gravitational field strength; 9.8 N/kg on Earth.
3. $E = 5 \times 9.8 \times 1.5 = 73.5 \text{ J}$.
4. GPE doubles, because $GPE \propto h$.
5. $E = 60 \times 9.8 \times 3 = 1764 \text{ J}$.

Part 3 of 3: Rearranging $E = mgh$

To find mass:	1
$m = \frac{E_{GP}}{g \times h}$	
To find height:	2
$h = \frac{E_{GP}}{m \times g}$	
To find g:	3
$g = \frac{E_{GP}}{m \times h}$	
Use the VESSS method: Values Equation Substitute Solve State units.	4

Questions

1. A ball has a GPE of 196 J and a mass of 2 kg. $g = 9.8 \text{ N/kg}$. Find the height.	(3)
2. A buzzard stores 5403 J of GPE at a height of 98 m. $g = 9.8 \text{ N/kg}$. Find its mass.	(3)
3. An object of mass 12 kg is at a height of 5 m and stores 588 J of GPE. Find g.	(3)
4. A 3 kg ball is dropped from 10 m. $g = 9.8 \text{ N/kg}$. Calculate the GPE lost.	(3)
5. A rock on the Moon ($g = 1.6 \text{ N/kg}$) has a mass of 20 kg and is 8 m high. Find its GPE.	(3)

Answers

1. $h = 196 \div (2 \times 9.8) = 10 \text{ m}$.
2. $m = 5403 \div (9.8 \times 98) = 5.63 \text{ kg}$.
3. $g = 588 \div (12 \times 5) = 9.8 \text{ N/kg}$.
4. $E = 3 \times 9.8 \times 10 = 294 \text{ J}$.
5. $E = 20 \times 1.6 \times 8 = 256 \text{ J}$.

Exam Question [7 marks]

Figure 1.1 shows a person sliding down a zip wire from height h.	
(a) The change in GPE is 1.47 kJ. The person's mass is 60 kg, $g = 9.8 \text{ N/kg}$. Calculate the change in vertical height.	(3)
(b) As the person moves down the zip wire, the increase in KE is less than the decrease in GPE. Explain why.	(2)
(c) Different people reach different speeds at the bottom. Explain why.	(2)

Mark Scheme

- (a) $1.47 \text{ kJ} = 1470 \text{ J}$. $h = 1470 \div (60 \times 9.8) = 2.5 \text{ m}$.
- (b) Some GPE is transferred to thermal energy due to friction/air resistance.
- (c) People have different masses, so the same GPE change gives different velocities.

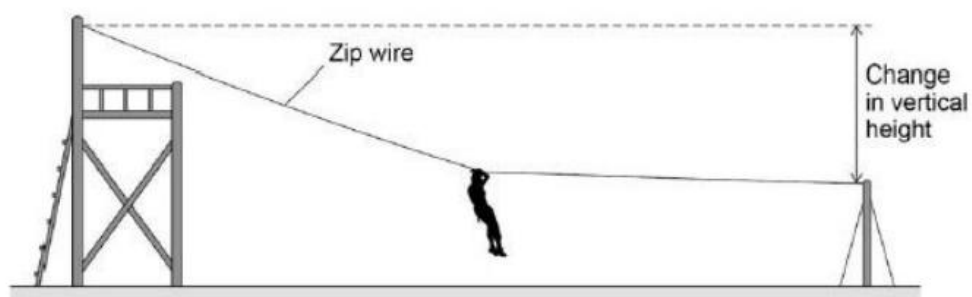


Fig 1.2 – Zip wire exam figure showing change in vertical height.

LESSON 2

Kinetic Energy

Do Now

1. What is the formula for gravitational potential energy?

$$E = mgh$$

2. What is the unit of energy?

Joule (J)

3. A 10 kg object is 5 m high. $g = 9.8 \text{ N/kg}$. Calculate its GPE.

$$E = 10 \times 9.8 \times 5 = 490 \text{ J}$$

4. What does "velocity" mean and how does it differ from speed?

Velocity is speed in a given direction (it is a vector quantity).

Part 1 of 3: Kinetic Energy

Kinetic energy (KE) is the energy stored in a moving object.	1
The formula for KE is: $E_k = \frac{1}{2} \times m \times v^2$	2
E_k = kinetic energy store (J); m = mass (kg); v = velocity (m/s).	3
Velocity is used (not speed) because KE depends on both magnitude and direction of motion.	4
Tip: calculate v^2 first, then multiply by $\frac{1}{2}m$. Using 0.5 for $\frac{1}{2}$ on a calculator avoids errors.	5

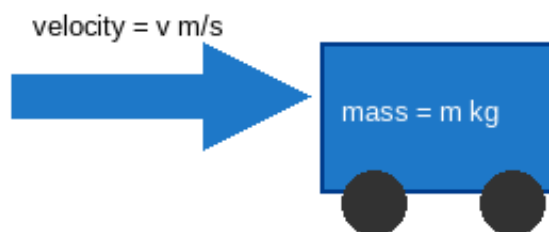


Fig 2.1 – An object of mass 4 kg moving at velocity 3 m/s.

Questions

1. Define kinetic energy store.	(1)
2. Write the formula for kinetic energy.	(1)
3. Why does a train waiting at a station have zero kinetic energy store?	(1)
4. A 4 kg object moves at 3 m/s. Calculate its KE.	(3)
5. A 0.2 kg ball moves at 5 m/s. Calculate its KE.	(3)

Answers

1. Energy stored in a moving object.

2. $E_k = \frac{1}{2}mv^2$.

3. Because it is stationary; $v = 0$.

4. $E = 0.5 \times 4 \times 9 = 18 \text{ J}$.

5. $E = 0.5 \times 0.2 \times 25 = 2.5 \text{ J}$.

Part 2 of 3: Rearranging $E_k = \frac{1}{2}mv^2$

To find mass:	1
$m = \frac{2E_k}{v^2}$	
To find velocity: $v = \sqrt{(2E_k / m)}$	2
A lorry moving at 30 mph has more KE than a car at the same speed because its mass is larger – $KE \propto m$.	3
KE increases with the square of velocity – doubling speed quadruples KE.	4

Questions

1. Why does a lorry at 30 mph have more KE than a car at the same speed?	(1)
2. A car of mass 1200 kg travels at 20 m/s. Calculate its KE.	(3)
3. An object has KE = 200 J and mass 25 kg. Find its velocity.	(3)
4. An object has KE = 450 J and velocity = 6 m/s. Find its mass.	(3)
5. How does doubling the velocity of an object affect its KE? Explain.	(2)

Answers

1. The lorry has a much greater mass, so even at the same velocity $KE = \frac{1}{2}mv^2$ is much larger.

2. $E = 0.5 \times 1200 \times 400 = 240\,000 \text{ J}$.

3. $v = \sqrt{(2 \times 200 \div 25)} = \sqrt{16} = 4 \text{ m/s}$.

4. $m = 2 \times 450 \div 36 = 25 \text{ kg}$.

5. KE is quadrupled because $KE \propto v^2$.

Part 3 of 3: Applying Kinetic Energy

KE and GPE are linked by conservation of energy. When an object falls, GPE converts to KE (ignoring air resistance).	1
If a 3 kg ball falls from 5 m: $GPE \text{ lost} = mgh = 3 \times 9.8 \times 5 = 147 \text{ J} = KE \text{ gained}$.	2
The maximum KE at the bottom equals the GPE at the top (in a closed system).	3

Questions

1. A trampolinist has KE = 8500 J and mass 65 kg. Find their velocity.	(3)
2. A 0.05 kg pancake is tossed with initial KE = 0.6 J. Calculate its initial velocity.	(3)
3. A 2 kg ball is dropped from 10 m. $g = 9.8 \text{ N/kg}$. What is its KE just before hitting the ground?	(3)
4. A cyclist of mass 70 kg (including bike) reaches 15 m/s. Calculate their KE.	(3)

Answers

1. $v = \sqrt{(2 \times 8500 \div 65)} = \sqrt{261.5} \approx 16.2 \text{ m/s.}$

2. $v = \sqrt{(2 \times 0.6 \div 0.05)} = \sqrt{24} \approx 4.9 \text{ m/s.}$

3. $GPE = 2 \times 9.8 \times 10 = 196 \text{ J} = KE.$

4. $E = 0.5 \times 70 \times 225 = 7875 \text{ J.}$

Exam Question [6 marks]

A ball of mass 0.5 kg is dropped from a height of 8 m. $g = 9.8 \text{ N/kg}$. Ignore air resistance.

(a) Calculate the gravitational potential energy of the ball before it is dropped.	(2)
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(b) State the kinetic energy of the ball just before it hits the ground.	(1)
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(c) Calculate the velocity of the ball just before it hits the ground.	(3)
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Mark Scheme

(a) $E = 0.5 \times 9.8 \times 8 = 39.2 \text{ J.}$

(b) 39.2 J (*GPE fully converted to KE*).

(c) $v = \sqrt{(2 \times 39.2 \div 0.5)} = \sqrt{156.8} \approx 12.5 \text{ m/s.}$

LESSON 3

Conservation of Energy & Dissipation

Do Now

1. State the Law of Conservation of Energy.

Energy cannot be created or destroyed, only transferred between stores.

2. What is a closed system?

A closed system is one where no energy enters or leaves.

3. A 2 kg ball moves at 4 m/s. Calculate its KE.

$$E = 0.5 \times 2 \times 16 = 16 \text{ J.}$$

4. A 3 kg ball is dropped from 5 m. $g = 9.8 \text{ N/kg}$. What is its KE just before hitting the ground?

$$E = 3 \times 9.8 \times 5 = 147 \text{ J.}$$

Part 1 of 3: Conservation of Energy

In a closed system , the total energy remains constant. Energy is transferred between stores but the total never changes.	1
Example: A ball thrown upward — KE converts to GPE as it rises; GPE converts back to KE as it falls.	2
In reality, no system is perfectly closed. Some energy is always transferred to the surroundings as thermal energy.	3
When a ball hits the ground, KE is transferred to sound and thermal energy stores — both are dissipated.	4

Questions

1. What is a closed system?	(1)
2. State the law of conservation of energy.	(2)
3. A 1 kg ball is thrown upward with KE = 20 J. What is its maximum GPE? Explain.	(2)
4. Why is no real system truly closed?	(2)
5. A 25 kg cannonball is fired upward at 8 m/s. $g = 9.8 \text{ N/kg}$. Find its maximum height.	(3)

Answers

1. A system in which no energy enters or leaves.

2. Energy cannot be created or destroyed; it can only be transferred between stores.

3. 20 J — all KE converts to GPE at the highest point.

4. Some energy is always lost to the surroundings (e.g. as heat/sound).

5. $KE = \frac{1}{2} \times 25 \times 64 = 800 \text{ J}$. $h = 800 \div (25 \times 9.8) = 3.27 \text{ m}$.

Part 2 of 3: Dissipation

Dissipation is when energy is transferred to the surroundings in a less useful form, usually thermal or sound.	1
Dissipated energy is "wasted" – it spreads into the surroundings and cannot be recovered easily.	2
Examples: friction in a car engine (thermal), air resistance on a cyclist (thermal), sound from brakes.	3
Reducing dissipation: lubrication reduces friction; streamlining reduces air resistance; insulation reduces thermal loss.	4

Questions

1. What does "dissipation" mean in physics?	(2)
2. Give two examples of energy dissipation in everyday life.	(2)
3. A bullet is shot upward with KE = 32 J. At its highest point its GPE = 31.8 J. Explain why the values differ.	(2)
4. Name two ways to reduce energy dissipation in machines.	(2)
5. Why is dissipated energy considered "wasted"?	(2)

Answers

1. Energy transferred to surroundings in a less useful (often thermal) form.
2. Any two: friction in engines, air resistance on vehicles, sound in brakes, heat from light bulbs.
3. 0.2 J was transferred to thermal energy/sound due to air resistance.
4. Lubrication (to reduce friction) and streamlining (to reduce air resistance).
5. Because it cannot easily be recovered and put back to useful work.

Part 3 of 3: Energy Transfers in Scenarios

When describing energy transfers, state the initial store mechanism of transfer final store(s) .	1
Zip wire: GPE (mechanically) KE + thermal (friction).	2
Bouncing ball: GPE KE (falling) elastic PE (squash) KE + thermal + sound (bounce).	3
The total energy at the end equals the total at the start; only the distribution changes.	4

Questions

1. Describe the energy transfer as a ball falls from a height (ignore air resistance).	(2)
2. Describe the energy transfers for a person braking on a bicycle.	(3)
3. A 60 kg person slides down a zip wire. GPE decreases by 1470 J but KE increases by only 1100 J. How much energy was dissipated?	(2)
4. Explain why a bouncing ball never bounces back to its original height.	(2)

Answers

1. GPE KE.
2. KE in cyclist thermal energy in brakes (friction) + sound.

3. $1470 - 1100 = 370 \text{ J}$ dissipated as thermal energy/sound.

4. Each bounce transfers some KE to thermal/sound, so less energy remains as KE/GPE.

Exam Question [6 marks]

A person of mass 60 kg slides down a zip wire. The change in vertical height is 2.5 m. $g = 9.8 \text{ N/kg}$.

- | | |
|--|-----|
| (a) Calculate the decrease in GPE. | (2) |
| (b) The increase in KE is 1100 J. Calculate the energy transferred to thermal energy. | (2) |
| (c) Explain why different people reach different speeds at the bottom. | (2) |

Mark Scheme

(a) $E = 60 \times 9.8 \times 2.5 = 1470 \text{ J}$.

(b) $1470 - 1100 = 370 \text{ J}$.

(c) Different masses same GPE loss gives different KE different velocities.

LESSON 4

Elastic Potential Energy

Do Now

1. What is meant by the term "energy store"?

A way energy can be held in an object.

2. What is the unit of the spring constant?

N/m (Newtons per metre)

3. What is the difference between compression and extension?

Compression = pushing together; extension = pulling apart.

4. If a spring with $k = 5 \text{ N/m}$ is stretched 2 m, what is its elastic potential energy?

$E = 0.5 \times 5 \times 4 = 10 \text{ J}$

Part 1 of 3: Elastic Potential Energy

Elastic potential energy (EPE) is stored when an elastic object (e.g. a spring) is stretched or compressed.	1
The formula is: $E_e = \frac{1}{2} \times k \times e^2$	2
E_e = elastic potential energy (J); k = spring constant (N/m); e = extension (m).	3
The extension is the extra length stretched – not the total length.	4
The spring constant k measures the stiffness of the spring. A higher k means a stiffer spring.	5
This formula is on the AQA formula sheet – you do not need to memorise it.	6

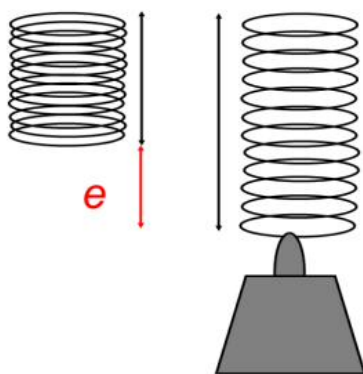


Fig 4.1 – A spring showing natural length and extension e .

Questions	
1. Define elastic potential energy store.	(1)
2. What two factors affect the elastic potential energy stored in a spring?	(2)
3. Do you need the total length of a spring to calculate its EPE? Explain.	(2)
4. A spring ($k = 2 \text{ N/m}$) is stretched 3 m. Calculate its EPE.	(3)
5. Which spring is easier to stretch: $k = 0.5 \text{ N/m}$ or $k = 40 \text{ N/m}$? Why?	(2)
Answers 1. Energy stored in a stretched or compressed elastic object. 2. Spring constant (k) and extension (e). 3. No – only the extension (extra length) is needed, not the total length. 4. $E = 0.5 \times 2 \times 9 = 9 \text{ J}$. 5. $k = 0.5 \text{ N/m}$ is easier – it has a lower spring constant so less force is needed.	

Part 2 of 3: Rearranging $E = \frac{1}{2}ke^2$	
To find spring constant: $k = \frac{2E_e}{e^2}$	1
To find extension: $e = \sqrt{(2E_e / k)}$	2
Example: A spring stores 18 J with $k = 4 \text{ N/m}$. Find the extension.	3
$e = \sqrt{(2 \times 18 / 4)} = \sqrt{9} = 3 \text{ m}$.	4

Questions	
1. A spring ($k = 75 \text{ N/m}$) is extended 40 cm. Calculate its EPE.	(3)
2. A spring stores 400 J with $k = 12 \text{ N/m}$. Find the extension.	(3)
3. A spring stores 50 J when extended 5 m. Calculate the spring constant.	(3)
4. A spring ($k = 200 \text{ N/m}$) has 180 J of EPE. Find the extension.	(3)
Answers 1. $E = 0.5 \times 75 \times 0.16 = 6 \text{ J}$. ($0.4 \text{ m} = 0.4$) 2. $e = \sqrt{(2 \times 400 \div 12)} = \sqrt{66.7} \approx 8.16 \text{ m}$. 3. $k = 2 \times 50 \div 25 = 4 \text{ N/m}$. 4. $e = \sqrt{(2 \times 180 \div 200)} = \sqrt{1.8} \approx 1.34 \text{ m}$.	

Part 3 of 3: Elastic Energy in Context

When a spring is released, elastic PE converts to KE (and some thermal).	1
A bungee cord stores elastic PE when stretched; when it pulls the jumper back, EPE converts to KE then GPE.	2
Elastic PE KE conversions occur in trampolines, bows, catapults and musical instruments.	3

Questions

1. Describe the energy transfers in a bow-and-arrow as the arrow is fired.	(3)
2. A 0.1 kg ball is fired by a spring ($k = 50 \text{ N/m}$, $e = 0.2 \text{ m}$). Assuming all EPE converts to KE, find the ball's velocity.	(4)
3. Give two examples of objects that store elastic potential energy.	(2)

Answers

1. Chemical energy in archer EPE in string KE in arrow (+thermal from friction).
2. $EPE = 0.5 \times 50 \times 0.04 = 1 \text{ J}$. $v = \sqrt{2 \times 1 \div 0.1} = \sqrt{20} \approx 4.47 \text{ m/s}$.
3. Any two: spring, rubber band, trampoline, bungee cord.

Exam Question [6 marks]

A bungee cord has spring constant $k = 15 \text{ N/m}$. A student of mass 70 kg jumps from a bridge. The unstretched cord length is 20 m .

- | | |
|--|-----|
| (a) Give two reasons why the cord must be appropriate for the student's weight. | (2) |
| (b) The cord stretches 18 m . Calculate the elastic PE stored. | (3) |
| (c) The student's KE at the lowest point is zero. Explain why. | (1) |

Mark Scheme

(a) *If too short/stiff the student won't reach maximum stretch; if too long/weak they may hit the ground.*

(b) $E = 0.5 \times 15 \times 18^2 = 0.5 \times 15 \times 324 = 2430 \text{ J}$.

(c) *At the lowest point, velocity = 0 so KE = 0.*

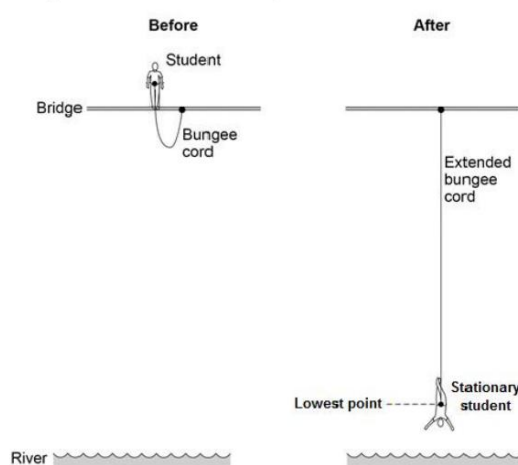


Fig 4.2 – Bungee jumper before and after jump: student at bridge level (Before) and at lowest point (After).

LESSON 5

Specific Heat Capacity

Do Now

1. What is thermal energy?

Energy stored due to the movement of particles in a substance.

2. What is the difference between temperature and thermal energy?

Temperature is the average KE per particle; thermal energy is the total energy stored.

3. If 500 J is added to two objects of different materials but equal mass, will they heat up equally?

No – different materials require different amounts of energy to raise temperature.

4. What unit is temperature measured in?

Degrees Celsius ($^{\circ}\text{C}$) or Kelvin (K).

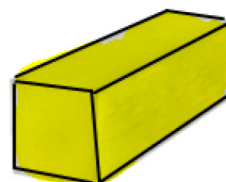
Part 1 of 3: Temperature and Thermal Energy

Temperature is the average kinetic energy store of the particles in a system.	1
Two blocks of equal mass but different materials will heat up by different amounts when given the same energy.	2
Copper has $\text{SHC} = 386 \text{ J/kg}^{\circ}\text{C}$; gold has $\text{SHC} = 126 \text{ J/kg}^{\circ}\text{C}$. Gold heats up faster with the same energy input.	3
The material that is "easier to heat up" has the lower specific heat capacity.	4



Copper

Specific heat capacity = $386 \text{ J/kg}^{\circ}\text{C}$



Gold

Specific heat capacity = $126 \text{ J/kg}^{\circ}\text{C}$

Fig 5.1 – Copper ($\text{SHC} = 386 \text{ J/kg}^{\circ}\text{C}$) and gold ($\text{SHC} = 126 \text{ J/kg}^{\circ}\text{C}$) blocks of equal mass. Adding 500 J raises gold's temperature more.

Questions

1. What does temperature measure at a particle level?	(1)
2. Two blocks of equal mass are given the same energy. One heats up more than the other. What can you conclude?	(2)
3. Which metal requires more energy to raise its temperature by 1°C per kg: copper or gold? Why?	(2)
4. Define the term "specific heat capacity".	(2)

Answers

1. The average kinetic energy store of the particles.
2. The one that heated up more has a lower specific heat capacity.
3. Copper – it has a higher SHC (386 vs 126 J/kg°C) so needs more energy per kg per °C.
4. The amount of energy required to raise the temperature of 1 kg of a substance by 1°C.

Part 2 of 3: The SHC Equation

The formula for thermal energy transfer is: $\Delta E = m \times c \times \Delta T$	1
ΔE = change in thermal energy (J); m = mass (kg); c = specific heat capacity (J/kg°C); ΔT = change in temperature (°C).	2
Example: Water ($c = 4200$ J/kg°C), mass 2 kg, heated by 10°C. $\Delta E = 2 \times 4200 \times 10 = 84\,000$ J.	3
The higher the SHC, the more energy needed to raise the temperature – water has one of the highest SHCs.	4
This equation is on the AQA formula sheet.	5

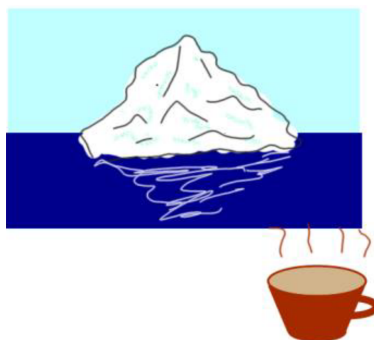


Fig 5.2 – Water has a very high SHC, which is why oceans moderate the climate.

Questions

1. Write the equation for specific heat capacity.	(1)
2. A 1 kg block of iron ($c = 450$ J/kg°C) is heated from 20°C to 70°C. Calculate the energy transferred.	(3)
3. A block of silver ($m = 12.5$ kg) is heated by 37°C. $c = 233$ J/kg°C. Calculate the thermal energy.	(3)
4. A 3 kg copper block absorbs 5790 J. $c = 386$ J/kg°C. Find the temperature change.	(3)

Answers

1. $\Delta E = mc\Delta T$.
2. $\Delta E = 1 \times 450 \times 50 = 22\,500$ J.
3. $\Delta E = 12.5 \times 233 \times 37 = 107\,763$ J.
4. $\Delta T = 5790 \div (3 \times 386) = 5$ °C.

Part 3 of 3: Rearranging $E = mc\Delta T$

To find mass:	1
$m = \frac{\Delta E}{c \times \Delta T}$	
To find SHC:	2
$c = \frac{\Delta E}{m \times \Delta T}$	
To find temperature change:	3
$\Delta T = \frac{\Delta E}{m \times c}$	
Water has $c = 4200 \text{ J/kg}^\circ\text{C}$ – this is why it is used in central heating systems (stores a lot of energy).	4

Questions

1. Find the mass of zinc needed to absorb 2300 J heated from 50°C to 61°C . $c = 387 \text{ J/kg}^\circ\text{C}$.	(4)
2. A 3.4 kg mass of water ($c = 4186 \text{ J/kg}^\circ\text{C}$) gains 6800 J. Find the temperature change.	(3)
3. Water in a kettle ($c = 4200 \text{ J/kg}^\circ\text{C}$, $m = 0.5 \text{ kg}$) is heated by 80°C . Calculate the energy used.	(3)
4. A material with $c = 500 \text{ J/kg}^\circ\text{C}$ absorbs 12 500 J with a 5°C rise. Find the mass.	(3)

Answers

- $m = 2300 \div (387 \times 11) = 0.54 \text{ kg}$.
- $\Delta T = 6800 \div (3.4 \times 4186) = 0.48^\circ\text{C}$.
- $\Delta E = 0.5 \times 4200 \times 80 = 168\,000 \text{ J}$.
- $m = 12500 \div (500 \times 5) = 5 \text{ kg}$.

Exam Question [6 marks]

A student heats 0.5 kg of water using a 100 W immersion heater for 5 minutes. The specific heat capacity of water is $4200 \text{ J/kg}^\circ\text{C}$.	
(a) Calculate the energy supplied by the heater in 5 minutes.	(2)
(b) Calculate the expected temperature rise of the water.	(3)
(c) The actual temperature rise is less than calculated. Give one reason why.	(1)

Mark Scheme

- $E = P \times t = 100 \times 300 = 30\,000 \text{ J}$.
- $\Delta T = 30000 \div (0.5 \times 4200) = 14.3^\circ\text{C}$.
- Some energy is transferred to the surroundings/container (heat loss).

LESSON 6

Investigating Specific Heat Capacity

Do Now

1. Write the equation for specific heat capacity.

$$\Delta E = mc\Delta T.$$

2. What does the specific heat capacity of a substance tell us?

How much energy is needed to raise the temperature of 1 kg of it by 1°C.

3. A 2 kg block is heated by 20°C. $c = 400 \text{ J/kg}^\circ\text{C}$. Calculate the energy transferred.

$$\Delta E = 2 \times 400 \times 20 = 16\,000 \text{ J}.$$

4. Why is water used in central heating systems?

Water has a very high SHC so it stores a lot of energy per kg.

Part 1 of 3: The SHC Investigation

Aim: to find the specific heat capacity of a metal block by measuring energy transferred and temperature change.	1
Equipment: metal block, immersion heater, thermometer, joulemeter (or ammeter + voltmeter + stopwatch), digital scales.	2
Method step 1: Measure the mass of the block using digital scales.	3
Method step 2: Apply glycerine to the immersion heater and thermometer to ensure good thermal contact with the block. Insert both.	4
Method step 3: Record the starting temperature and joulemeter reading.	5
Method step 4: Switch on the heater. Record temperature and energy at regular intervals for 10 minutes.	6
Method step 5: Use $\Delta E = mc\Delta T$ to calculate c .	7

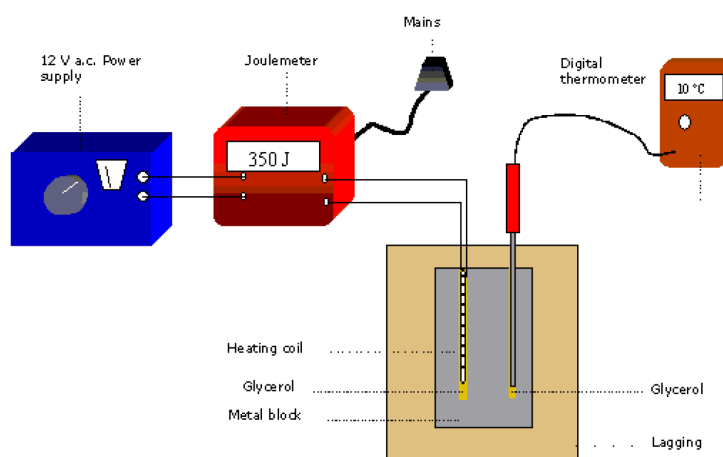


Fig 6.1 – SHC apparatus: 12V power supply, joulemeter, immersion heater and thermometer in a lagged metal block.

Questions	
1. Name the key pieces of equipment for the SHC investigation.	(3)
2. Why is glycerine applied to the heater and thermometer?	(2)
3. What measurements must be taken during the experiment?	(3)
4. Why is it important to insulate (lag) the metal block?	(2)
Answers 1. Metal block, immersion heater, thermometer, joulemeter/ammeter+voltmeter, digital scales. 2. To ensure good thermal contact (transfers heat more efficiently). 3. Mass of block, starting temperature, energy supplied (joulemeter), temperature at intervals. 4. To reduce heat loss to the surroundings and improve accuracy.	

Part 2 of 3: Analysing Results	
Calculate c using:	1
$c = \frac{\Delta E}{m \times \Delta T}$	
Plot a graph of temperature (y-axis) against energy supplied (x-axis). The gradient = $1/(mc)$.	2
Possible errors: heat loss to surroundings (c appears too high); poor thermal contact (uneven heating).	3
To improve: use lagging; allow system to reach thermal equilibrium; repeat and average.	4
Compare calculated c with the known value (e.g. aluminium: 900 J/kg°C). Discuss percentage error.	5

Questions	
1. A student heats a 0.5 kg aluminium block. Energy supplied = 4500 J; $\Delta T = 10^\circ\text{C}$. Calculate c.	(3)
2. The known SHC of aluminium is 900 J/kg°C. Calculate the percentage error.	(2)
3. A student carried out an experiment with 100 g (0.1 kg) of water in sunlight for 30 minutes. The temperature rose by 3°C . $c = 4200 \text{ J/kg}^\circ\text{C}$. Find the energy absorbed.	(2)
4. Suggest one improvement to increase the accuracy of the SHC experiment.	(2)
Answers 1. $c = 4500 \div (0.5 \times 10) = 900 \text{ J/kg}^\circ\text{C}$. 2. % error = 0% — matches exactly. 3. $\Delta E = 0.1 \times 4200 \times 3 = 1260 \text{ J}$. 4. Any valid: better insulation, more accurate thermometer, repeat measurements.	

Part 3 of 3: Evaluating the SHC Investigation

Sources of error: heat loss to surroundings; thermal lag (thermometer not reaching equilibrium); poor contact.	1
Systematic errors: if the joulemeter is not zeroed; if mass measurement is incorrect.	2
Reliability: repeat the experiment and average values; use a data logger for precision.	3
Variables: independent = energy supplied; dependent = temperature change; controlled = mass, material, insulation.	4

Questions

1. What is the independent variable in the SHC investigation?	(1)
2. What is the dependent variable?	(1)
3. Give two sources of error that could make the calculated c too high.	(2)
4. How could you check if your result is repeatable?	(1)
5. Why should you record temperature over time rather than just at the end?	(2)

Answers

1. Energy supplied (joulemeter reading).
2. Temperature change.
3. Heat loss to surroundings; poor thermal contact between heater and block.
4. Repeat the experiment and compare values.
5. Allows you to identify when temperature stabilises and spot anomalies.

Exam Question [5 marks]

A student investigates the specific heat capacity of a metal block of mass 0.8 kg. The immersion heater supplies 3600 J of energy. The temperature rises from 20°C to 25°C.	
(a) Calculate the specific heat capacity of the metal.	(3)
(b) The student's value is higher than the accepted value. Give one reason why.	(1)
(c) Suggest one way to reduce this source of error.	(1)

Mark Scheme

- (a) $c = 3600 \div (0.8 \times 5) = 900 \text{ J/kg}^\circ\text{C}.$
- (b) Heat was lost to the surroundings so less energy went into the block.
- (c) Insulate/lag the block to reduce heat loss.

LESSON 7

Power

Do Now

Gravitational Potential Energy: $E_{GP} = m \times g \times h$ Kinetic Energy: $E_k = \frac{1}{2} \times m \times v^2$

1. What is the unit of energy?

*Joule (J).*2. Calculate the GPE of a 3 kg object at a height of 5 m. $g = 9.8 \text{ N/kg}$.

$$E_{GP} = 3 \times 9.8 \times 5 = 147 \text{ J.}$$

3. A 20 kg object is 8 m high. $g = 9.8 \text{ N/kg}$. Calculate its GPE.

$$E_{GP} = 20 \times 9.8 \times 8 = 1568 \text{ J.}$$

4. A 4 kg ball moves at 6 m/s. Calculate its kinetic energy.

$$E_k = 0.5 \times 4 \times 36 = 72 \text{ J.}$$

5. A ball has a kinetic energy of 72 J and a mass of 4 kg. Calculate its speed.

$$v^2 = (2 \times 72) / 4 = 36; v = \sqrt{36} = 6 \text{ m/s.}$$

Part 1 – Watt is Power?

Work done is energy transferred.	1
Rate means how much each second.	2
Power is the rate at which energy is transferred.	3
Watt is the unit of power.	4

Questions

1. What is work done?	(1)
2. What does rate mean?	(1)
3. Define power.	(1)
4. What is the unit of power?	(1)

Answers

1. Work done is energy transferred.
2. Rate means how much per second.
3. Power is the rate at which energy is transferred.
4. The Watt (W).

Part 2 – Calculating Power

Formula 1:	1
$P = \frac{E}{t}$	
Formula 2:	2
$P = \frac{W}{t}$	
P = power (W)	3
E = Energy Transferred (J)	4
t = time (s)	5

Example 1

Values	$P = ? \ E = 600 \text{ J} \ t = 12 \text{ s}$
Equation	$P = \frac{E}{t}$
Substitute	$P = \frac{600}{12}$
Solve	$P = 50$
Units	Watts (W)

Questions

5. A lamp transfers 200 J in 4 s. Calculate its power.	(2)
6. A heater transfers 6000 J in 60 s. Calculate its power.	(2)
7. An electric motor transfers 2400 J in 8 s. Calculate its power.	(2)
8. A car engine transfers 84 000 J in 60 s. Calculate its power.	(3)

Answers

5. $P = 200 / 4 = 50 \text{ W}.$

6. $P = 6000 / 60 = 100 \text{ W}.$

7. $P = 2400 / 8 = 300 \text{ W}.$

8. $P = 84\,000 / 60 = 1400 \text{ W}.$

1 Watt means 1 Joule per second.	1
1 kJ = 1000 J	2
1 min = 60 s	3

Example 2: a machine transfers 1.2 kJ in 2 minutes, calculate its power

V	$P = ?$ $E = 1.2 \times 1000 = 1200 \text{ J}$ $t = 2 \times 60 = 120 \text{ s}$
E	$P = \frac{E}{t}$
S	$P = \frac{1200}{120}$
S	$P = 10$
U	Watts (W)

Questions

9. A device transfers 3 kJ of energy in 30 s. Calculate its power.	(3)
10. An appliance transfers 1800 J of energy in 3 minutes. Calculate its power.	(3)
11. A motor transfers 4.8 kJ of energy in 60 s. Calculate its power.	(3)
12. A lamp transfers 3.6 kJ of energy in 3 minutes. Calculate its power.	(3)
13. Two motors both lift the same weight the same height. Motor A takes 5 s; Motor B takes 20 s. Which is more powerful? Explain.	(2)

Answers

9. Convert: $E = 3 \times 1000 = 3000 \text{ J}$. $P = 3000 / 30 = 100 \text{ W}$.

10. Convert: $t = 3 \times 60 = 180 \text{ s}$. $P = 1800 / 180 = 10 \text{ W}$.

11. Convert: $E = 4.8 \times 1000 = 4800 \text{ J}$. $P = 4800 / 60 = 80 \text{ W}$.

12. Convert: $E = 3.6 \times 1000 = 3600 \text{ J}$; $t = 3 \times 60 = 180 \text{ s}$. $P = 3600 / 180 = 20 \text{ W}$.

13. Motor A – same energy transferred in less time, so power (E/t) is greater.

Part 3 – Finding Energy or Time

Example 3 (finding energy)		Example 4 (finding time)	
V	$E = ? P = 250 \text{ W } t = 2 \text{ min} = 120 \text{ s}$	V	$t = ? P = 500 \text{ W } E = 15\,000 \text{ J}$
E	$P = \frac{E}{t}$	E	$P = \frac{E}{t}$
S	$250 = \frac{E}{120}$	S	$500 = \frac{15\,000}{t}$
S	$250 \times 120 = E = 30\,000$	S	$500t = 15\,000$
U	Joules (J)	S	$t = \frac{15\,000}{500} = 30$
		U	Seconds (s)

Questions

14. A 40 W fan runs for 5 s. How much energy does it transfer?	(2)
15. A 250 W lamp runs for 2 minutes. Calculate the energy transferred.	(3)
16. A 3 kW kettle heats water for 4 minutes. Calculate the energy transferred in kJ.	(3)
17. A 60 W electric fan runs for 30 minutes. Calculate the energy transferred in kJ.	(3)

Answers

- 14.** $E = P \times t = 40 \times 5 = 200 \text{ J}.$
- 15.** $E = P \times t = 250 \times 120 = 30\,000 \text{ J}.$
- 16.** $E = P \times t = 3000 \times 240 = 720\,000 \text{ J} = 720 \text{ kJ}.$
- 17.** $E = P \times t = 60 \times 1800 = 108\,000 \text{ J} = 108 \text{ kJ}.$

Questions

18. A device transfers 18 000 J at a power of 300 W. How long does it run for?	(3)
19. A battery stores 900 000 J. A 50 W lamp is connected. How many hours will it run?	(3)
20. A 2 kW motor transfers 480 000 J. How long does it take? Give your answer in minutes.	(3)

Answers

- 18.** $t = E / P = 18\,000 / 300 = 60 \text{ s}.$
- 19.** $t = E / P = 900\,000 / 50 = 18\,000 \text{ s}; 18\,000 / 3600 = 5 \text{ hours}.$
- 20.** $t = E / P = 480\,000 / 2000 = 240 \text{ s}; 240 / 60 = 4 \text{ minutes}.$

Part 4 – 2 Step Calculations

A motor lifts a 50 kg rock through a height of 4 m in 8 s. $g = 9.8 \text{ N/kg}$. Calculate the power of the motor.

Step 1 – Calculate GPE		Step 2 – Calculate Power	
V	$E = ? \quad m = 50 \text{ kg} \quad h = 4 \text{ m} \quad g = 9.8 \text{ N/kg}$	V	$P = ? \quad E = 1960 \text{ J} \quad t = 8 \text{ s}$
E	$E = m \times g \times h$	E	$P = \frac{E}{t}$
S	$E = 50 \times 9.8 \times 4$	S	$P = \frac{1960}{8}$
S	$E = 1960$	S	$P = 245$
U	Joules (J)	U	Watts (W)

Two-Step Question [5 marks]

A crane lifts a 150 kg load through a height of 8 m in 12 s. $g = 9.8 \text{ N/kg}$.

- | | |
|--|-----|
| (a) Calculate the gravitational potential energy gained by the load. | (2) |
| (b) Using your answer to (a), calculate the power of the crane. | (2) |
| (c) State the unit of power. | (1) |

Mark Scheme

- (a) Substitution: $E = 150 \times 9.8 \times 8$ (1 mark). Answer: $E = 11\,760 \text{ J}$ (1 mark).
 (b) Substitution: $P = 11\,760 / 12$ (1 mark). Answer: $P = 980 \text{ W}$ (1 mark).
 (c) Watt (W) (1 mark).

Two-Step Question [5 marks]

A pump raises 60 kg of water through a height of 5 m in 6 s. $g = 9.8 \text{ N/kg}$.

- | | |
|---|-----|
| (a) Calculate the gravitational potential energy gained by the water. | (2) |
| (b) Calculate the power of the pump. | (2) |
| (c) State the unit of power. | (1) |

Mark Scheme

- (a) Substitution: $E = 60 \times 9.8 \times 5$ (1 mark). Answer: $E = 2940 \text{ J}$ (1 mark).
 (b) Substitution: $P = 2940 / 6$ (1 mark). Answer: $P = 490 \text{ W}$ (1 mark).
 (c) Watt (W) (1 mark).

Questions

- | | |
|--|-----|
| 21. A 75 kg person climbs stairs of height 4 m in 8 s. $g = 9.8 \text{ N/kg}$. Calculate power. | (3) |
| 22. A 90 kg weightlifter raises a bar 1.8 m in 2 s. $g = 9.8 \text{ N/kg}$. Calculate power. | (3) |
| 23. A motor transfers 540 000 J in 15 minutes. Calculate its power in W and in kW. | (3) |

Answers

21. $E = 75 \times 9.8 \times 4 = 2940 \text{ J}; P = 2940 / 8 = 367.5 \text{ W}.$

22. $E = 90 \times 9.8 \times 1.8 = 1587.6 \text{ J}; P = 1587.6 / 2 \approx 794 \text{ W}.$

23. $P = 540\,000 / 900 = 600 \text{ W} = 0.6 \text{ kW}.$

Exam Question [6 marks]

A crane lifts a 400 kg steel beam through a height of 15 m. $g = 9.8 \text{ N/kg}.$

(a) Calculate the gravitational potential energy gained by the steel beam.	(2)
---	-----

(b) The crane takes 40 seconds to lift the beam. Calculate the power of the crane.	(2)
---	-----

(c) A second crane lifts the same beam through the same height but takes only 25 seconds. Calculate the power of the second crane.	(2)
---	-----

Mark Scheme

(a) $E = mgh = 400 \times 9.8 \times 15 = 58\,800 \text{ J}.$

(b) $P = E/t = 58\,800 / 40 = 1470 \text{ W}.$

(c) $P = E/t = 58\,800 / 25 = 2352 \text{ W}.$

LESSON 8

Energy Stores & Transfers

Do Now

1. Name four energy stores.

Any four: kinetic, gravitational, elastic, thermal, chemical, nuclear, electrostatic, magnetic.

2. Name four ways energy can be transferred.

Any four: mechanically, electrically, by radiation (light/sound), by heating.

3. Describe the energy transfer when a candle burns.

Chemical store thermal + light (by heating and radiation).

4. What is meant by the "rate" of energy transfer?

How quickly energy is transferred (power in Watts).

Part 1 of 3: Energy Stores Recap

The four main stores studied so far: Gravitational ($E=mgh$), Kinetic ($E=\frac{1}{2}mv^2$), Elastic ($E=\frac{1}{2}ke^2$), Thermal ($E=mc\Delta T$).	1
Other stores: Chemical (food, fuel, batteries), Nuclear (uranium), Electrostatic (charged objects), Magnetic (magnets).	2
Energy is transferred when something happens. Transfers can be shown as bar models or Sankey diagrams.	3
In a bar model, the total height of bars stays constant (conservation) while the energy distributes between stores.	4

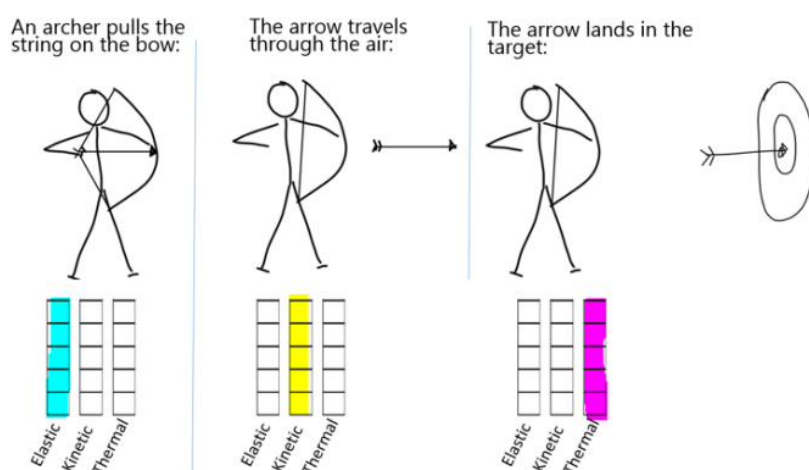


Fig 8.1 – Energy store bar models for an archer firing an arrow: elastic kinetic as the arrow travels.

Questions	
1. Name the eight energy stores.	(4)
2. What energy store does a charged capacitor have?	(1)
3. Describe the energy stores at each stage as an archer fires an arrow and it lands in a target.	(4)
4. Why do the bars in a bar model always add up to the same total?	(2)

Answers

1. Kinetic, gravitational, elastic, thermal, chemical, nuclear, electrostatic, magnetic.
2. Electrostatic.
3. Pulling back: chemical elastic. Arrow in air: elastic kinetic. Landing: kinetic thermal + sound.
4. Conservation of energy – energy is never created or destroyed.

Part 2 of 3: Energy Transfer Mechanisms	
Energy is transferred between stores by: Mechanical working (forces), Electrical working (current), Heating (conduction/convection/radiation), Radiation (light, sound, etc.).	1
The rate of energy transfer is power (Watts).	2
Example – electric motor: electrical (electrical working) kinetic + thermal.	3
Example – burning fuel: chemical (heating) thermal + (radiation) light.	4

Questions	
1. Name the four mechanisms by which energy can be transferred.	(2)
2. A boy falls on a trampoline. Describe the energy transfers.	(4)
3. A jack-in-the-box pops open. Describe the energy transfers.	(3)
4. A weight hangs on a spring and oscillates. Describe the energy transfers.	(3)

Answers

1. Mechanical working, electrical working, heating, radiation.
2. GPE KE (falling) elastic PE (trampoline deforms) KE (bouncing) + thermal + sound.
3. Chemical (spring compressed) elastic PE KE + sound (when released).
4. KE EPE continually, with some thermal dissipated each cycle.

Part 3 of 3: Energy Transfer Diagrams	
A Sankey diagram shows energy transfers with arrow widths proportional to energy values.	1
Useful energy goes forwards (horizontal); wasted energy goes downward (usually thermal).	2
For a car engine: 1000 J input 250 J kinetic (forward) + 750 J thermal (down).	3
Efficiency can be read from a Sankey diagram:	4
$\text{efficiency} = \frac{\text{useful output}}{\text{total input}}$	

Questions	
1. What does the width of an arrow in a Sankey diagram represent?	(1)
2. Which direction does wasted energy usually point in a Sankey diagram?	(1)
3. A light bulb uses 100 J and emits 10 J as light. Sketch/describe its Sankey diagram.	(3)
4. Describe the energy transfers in a bungee jumper from jump to lowest point.	(4)
Answers 1. <i>The amount of energy being transferred.</i> 2. <i>Downward.</i> 3. <i>100 J input 10 J light (forward, narrow arrow) + 90 J thermal (down, wide arrow).</i> 4. <i>GPE KE (falling freely) elastic PE + KE (cord stretching) elastic PE only (at lowest point).</i>	
Exam Question [7 marks]	
A student jumps off a bridge on a bungee cord. The cord has an unstretched length of 20 m.	
(a) Give two reasons why it is important that the cord is appropriate for the student's weight.	(2)
(b) The student falls. Describe the energy transfers before the cord starts to stretch.	(2)
(c) When the cord is stretched, state the energy store in the cord.	(1)
(d) The student's GPE decreases by 29 400 J. KE increases by 18 000 J. What has happened to the rest of the energy?	(2)
Mark Scheme (a) <i>Too weak: won't stop the student in time/hits ground. Too stiff: gives dangerous deceleration.</i> (b) <i>GPE KE as student falls (before cord tenses).</i> (c) <i>Elastic potential energy.</i> (d) <i>$29400 - 18000 = 11400$ J stored as elastic PE in the cord.</i>	

LESSON 9

Reducing Wasted Energy

Do Now

1. What is dissipation?

Energy transferred to the surroundings in a less useful form.

2. Give two examples of wasted energy in a car engine.

Thermal energy from friction; sound from the engine.

3. What is thermal conductivity?

How quickly a material allows thermal energy to pass through it.

4. Why does a metal spoon feel colder than a wooden spoon at the same temperature?

Metal has higher thermal conductivity so it conducts heat away from your hand faster.

Part 1 of 3: Thermal Insulation

Thermal insulation reduces the rate of energy transfer to the surroundings.	1
Methods: cavity wall insulation, loft insulation (foil or foam), double glazing, draught excluders.	2
Best insulating materials have low thermal conductivity (e.g. foam, wool, air gaps).	3
High thermal conductivity = faster energy transfer. Low thermal conductivity = slower transfer.	4
Metal has high thermal conductivity; foam has low thermal conductivity.	5

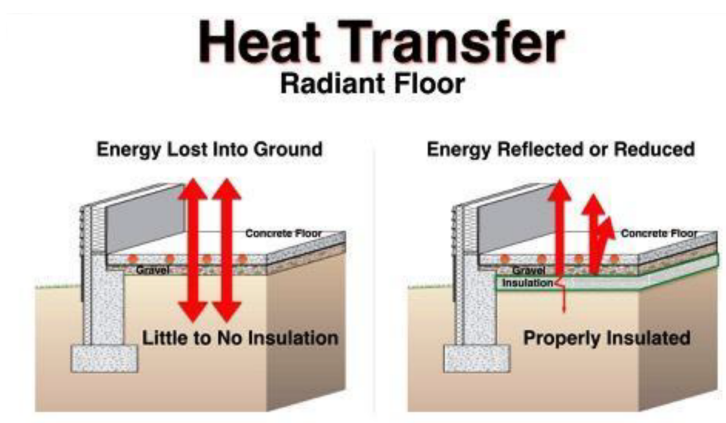


Fig 9.1 – Heat transfer through an uninsulated floor (energy lost downward) vs. insulated floor (energy reflected/reduced).

Questions	
1. Why do people want to reduce unwanted energy transfers?	(2)
2. Give an example of an unwanted energy transfer in a sewing machine.	(1)
3. Explain how unwanted energy transfer is reduced in heated buildings.	(2)
4. Relate thermal conductivity to rate of energy transfer.	(2)
5. How does the thickness of a wall affect a building's rate of cooling?	(2)
6. How does the thermal conductivity of walls affect a building's rate of cooling?	(2)
Answers 1. To save money/energy, improve efficiency, reduce environmental impact. 2. KE thermal due to friction between moving parts. 3. Cavity wall insulation, double glazing, loft insulation — all reduce conduction/convection. 4. Higher thermal conductivity faster energy transfer through the material. 5. Thicker walls slower rate of cooling (more insulation). 6. Lower thermal conductivity slower rate of cooling.	

Part 2 of 3: Reducing Friction & Other Losses	
Lubrication (oil/grease) reduces friction between moving surfaces, reducing thermal energy waste.	1
Streamlining reduces air resistance, reducing thermal energy wasted in vehicles.	2
Insulation around pipes and tanks reduces thermal energy loss by conduction.	3
In electrical devices, thicker wires reduce resistance and therefore reduce heating losses.	4

Questions	
1. Explain how lubrication reduces energy waste in engines.	(2)
2. Why are racing cars designed to be streamlined?	(2)
3. How does insulating a hot water pipe reduce energy waste?	(2)
4. A house loses 20% of heat through the roof. Suggest one way to reduce this.	(1)
Answers 1. Oil reduces friction between metal surfaces, so less KE is converted to thermal energy. 2. Streamlining reduces air resistance, so less KE is converted to thermal energy at high speed. 3. Insulation reduces conduction from the hot pipe to cooler surroundings. 4. Loft insulation / fibre glass in the roof space.	

Part 3 of 3: Reducing Energy Waste – Hot Water Tanks

A copper hot water tank loses energy quickly because copper has high thermal conductivity.	1
Insulation (foam jacket) around the tank reduces the rate of energy transfer to the room.	2
An insulated tank keeps water hot for longer, reducing the need to reheat it.	3
The electric immersion heater inside the tank converts electrical energy to thermal energy.	4

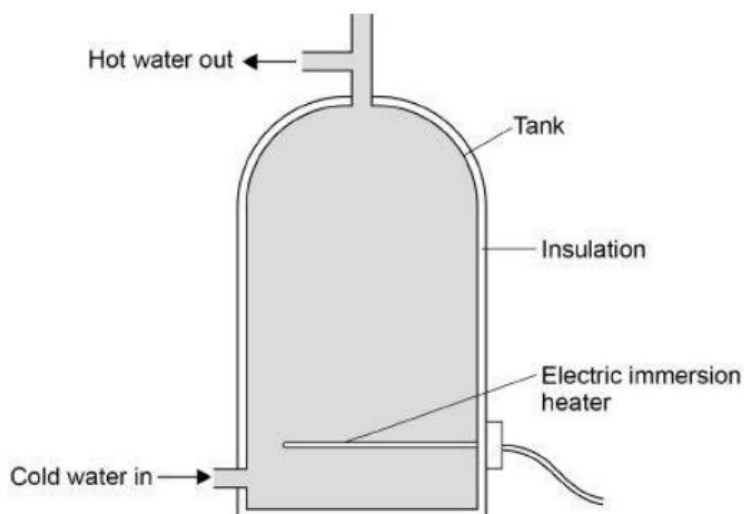


Fig 9.2 – Insulated hot water tank showing tank, insulation layer and electric immersion heater.

Questions

1. Why does a copper hot water tank lose heat quickly?	(1)
2. How does a foam jacket reduce heat loss from the tank?	(2)
3. Compared to an uninsulated tank, how does the rate of energy transfer change?	(1)
4. Explain why insulating a hot water tank saves money.	(2)

Answers

1. Copper has high thermal conductivity so conducts heat to surroundings rapidly.
2. Foam has low thermal conductivity so slows conduction from tank to air.
3. The rate of energy transfer is reduced (slower cooling).
4. Water stays hot longer immersion heater needed less often lower electricity bill.

Exam Question [5 marks]

Figure 9.2 shows a copper hot water tank with insulation.

(a) Copper has higher thermal conductivity than most metals. How does the rate of energy transfer compare to most metals? Tick one box: Higher / Lower / The same.	(1)
(b) The tank is insulated. The water is heated, then the heater switches off. Compare the rate of cooling with and without insulation.	(2)
(c) During one morning, 4 070 000 J is transferred from the heater. 4 030 000 J goes to the water. Calculate the proportion of energy transferred to the water.	(2)

Mark Scheme

(a) Higher.

(b) With insulation, the rate of energy transfer to the room is reduced so the water stays hotter for longer.

(c) $4030000 \div 4070000 = 0.990$ (99.0%).

LESSON 10

Efficiency

Do Now

1. What is meant by "wasted" energy?

Energy transferred to the surroundings in a less useful form.

2. Give two examples of useful energy outputs from a car engine.

Kinetic energy (motion) and possibly electrical energy (alternator).

3. What is the formula for power?

$$P = E/t.$$

4. A 500 W machine runs for 20 s. How much energy does it transfer?

$$E = 500 \times 20 = 10\,000 \text{ J.}$$

Part 1 of 3: What is Efficiency?

Efficiency is the fraction of input energy that is transferred to a useful output.	1
Formula 1: $\text{Efficiency} = \frac{\text{useful output energy}}{\text{total input energy}}$	2
Formula 2: $\text{Efficiency} = \frac{\text{useful output power}}{\text{total input power}}$	3
Efficiency has no units. It is between 0 and 1 (or expressed as a percentage 0–100%).	4
No machine is 100% efficient – some energy is always dissipated as thermal or sound.	5

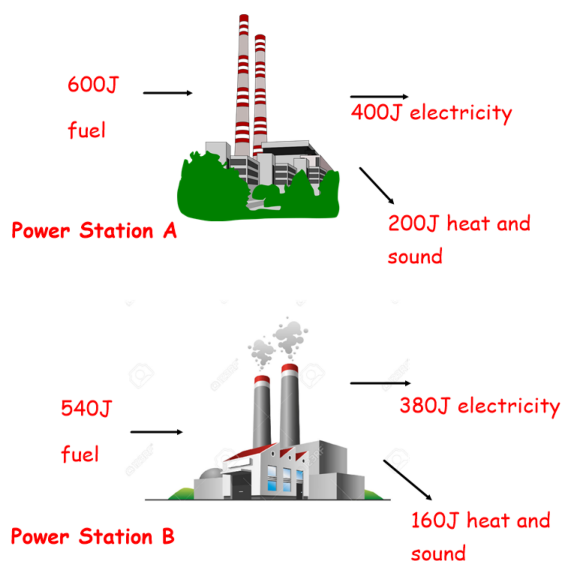


Fig 10.1 – Power Station A (efficiency = $400 \div 600 = 0.67$) vs Power Station B (efficiency = $380 \div 540 = 0.70$). Station B is more efficient.

Questions	
1. What does the efficiency of an appliance tell us?	(2)
2. Write both equations for efficiency.	(2)
3. Why would a more efficient motor give a car a higher top speed?	(2)
4. A loudspeaker uses 400 W and produces 325 W of sound. Find its efficiency.	(3)
5. A car uses 3890 J of fuel to generate 2650 J of KE. Find its efficiency.	(3)
Answers 1. What fraction of the total input energy is transferred to a useful output. 2. $\text{Eff} = \text{useful output } E \div \text{total input } E$; $\text{Eff} = \text{useful output } P \div \text{total input } P$. 3. More KE output per unit of fuel reaches higher speed before air resistance balances thrust. 4. $\text{Eff} = 325 \div 400 = 0.81 = 81\%$. 5. $\text{Eff} = 2650 \div 3890 = 0.68 = 68\%$.	

Part 2 of 3: Calculating and Applying Efficiency	
Example: A lightbulb uses 470 J, emits 180 J as heat and 290 J as light. Efficiency = $290/470 = 0.617$.	1
To find wasted energy: wasted = input - useful output.	2
Increasing efficiency: lubrication, streamlining, better insulation, using waste heat (CHP).	3
CHP (Combined Heat and Power) stations recapture waste steam to heat homes, greatly increasing overall efficiency.	4

Questions	
1. A lightbulb uses 470 J; 180 J is heat and 290 J is light. Find the efficiency.	(3)
2. A power station uses 2000 J of fuel to generate 600 J of electricity. How much energy is wasted?	(2)
3. An electric motor uses 2.4×10^4 J to give a weight 1.8×10^4 J of GPE. Find efficiency.	(3)
4. A lightbulb (efficiency 0.4) emits 3000 J of light in 20 s. Find the power input.	(3)
Answers 1. $\text{Eff} = 290 \div 470 = 0.617$. 2. $2000 - 600 = 1400$ J wasted. 3. $\text{Eff} = 1.8 \times 10^4 \div 2.4 \times 10^4 = 0.075 = 7.5\%$. 4. Useful power = $3000 \div 20 = 150$ W. Input $P = 150 \div 0.4 = 375$ W.	

Part 3 of 3: Efficiency as a Percentage & Increasing It

To express as percentage: multiply the decimal by 100 (e.g. 0.67 = 67%).	1
Wasted energy is usually thermal. Reducing thermal losses increases efficiency.	2
Environmental argument: more efficient appliances use less fuel lower CO emissions.	3
Economic argument: more efficient appliances cost less to run.	4

Questions

1. Convert efficiency 0.82 to a percentage.	(1)
2. A power station uses 2000 J to produce 600 J electricity. For every 600 J of electricity, how much fuel is used?	(2)
3. State two reasons why improving efficiency is desirable.	(2)
4. A fan uses 180 W and delivers 150 W of useful power to the air. Calculate its efficiency.	(3)

Answers

1. 82%.
2. 2000 J of fuel needed for every 600 J of electricity.
3. Saves money; reduces fuel consumption and environmental impact.
4. $\text{Eff} = 150 \div 180 = 0.833 = 83.3\%$.

Exam Question [6 marks]

A fuel burning power station uses 2000 J of fuel energy to generate 600 J of electrical energy.	
(a) Calculate the efficiency of the power station.	(2)
(b) State where the rest of the energy goes.	(1)
(c) A second power station has efficiency 0.70. For every 1000 J of fuel, how much electricity does it produce?	(2)
(d) Give one way the second power station could increase its efficiency.	(1)

Mark Scheme

- (a) $\text{Eff} = 600 \div 2000 = 0.3 = 30\%$.
- (b) Thermal energy transferred to the surroundings (wasted heat).
- (c) $0.70 \times 1000 = 700 \text{ J}$.
- (d) Use CHP to capture waste steam heat; reduce friction in turbines; better insulation.

LESSON 11

Non-Renewable Energy Resources

Do Now

1. What is meant by a "non-renewable" energy resource?

A resource that cannot be replenished at the rate at which it is used.

2. Name three fossil fuels.

Coal, oil, natural gas.

3. What gas is released when fossil fuels are burned?

Carbon dioxide (CO₂) – a greenhouse gas.

4. What is nuclear fission?

The splitting of a heavy atomic nucleus (e.g. uranium) releasing large amounts of energy.

Part 1 of 3: Fossil Fuels

Fossil fuels (coal, oil, natural gas) formed from ancient organisms over millions of years. They are non-renewable .	1
Fossil fuels store chemical energy . When burned, chemical energy thermal electrical (via turbine/generator).	2
Advantages: reliable, high energy density, existing infrastructure.	3
Disadvantages: non-renewable (will run out ~50 years); produce CO ₂ (greenhouse gas/climate change); coal also produces SO ₂ (acid rain).	4
They provide a consistent, controllable supply – useful for meeting peak demand.	5

Questions

1. State three things humans use energy resources for.	(3)
2. Define "non-renewable".	(2)
3. Name three common non-renewable energy resources.	(3)
4. What are the benefits of fossil fuels?	(2)
5. When are fossil fuels likely to run out?	(1)
6. Name two things formed when fossil fuels are burned and explain the problems they cause.	(4)

Answers

1. Electricity generation, heating, transport.

2. A resource that cannot be replenished as fast as it is consumed; it will eventually run out.

3. Coal, oil, natural gas (and nuclear counts as non-renewable).

4. Reliable, high energy density, existing infrastructure, controllable output.

5. Approximately 50 years.

6. CO₂ greenhouse effect/climate change; SO₂ (from coal) acid rain/respiratory problems.

Part 2 of 3: Nuclear Fuels

Nuclear fuels (uranium, plutonium) are non-renewable but will last ~80 years.	1
Nuclear fission: heavy nucleus absorbs a neutron and splits, releasing large amounts of energy as heat.	2
Advantages: no CO emissions during operation; very high energy density; reliable.	3
Disadvantages: expensive to build; produces radioactive waste (difficult to dispose of safely); risk of contamination if accident occurs.	4
Scientists research nuclear fusion (joining light nuclei) which would be cleaner but is not yet commercially viable.	5

Questions

1. Explain why nuclear energy is non-renewable.	(2)
2. What are the risks with using nuclear power?	(3)
3. What are the benefits of nuclear power compared to fossil fuels?	(3)
4. What is nuclear fusion and why is it not yet used commercially?	(3)

Answers

1. Uranium and plutonium are finite resources; they will eventually run out.
2. Radioactive waste is toxic and hard to dispose of; risk of accidental contamination of surroundings.
3. No CO produced; much longer-lasting fuel; much higher energy density per kg.
4. Fusion joins light nuclei releasing enormous energy; not yet commercially viable because containing the plasma requires more energy than it produces currently.

Part 3 of 3: UK Energy Mix

The UK uses a mix of energy resources. In 2018, gas and nuclear provided the majority of electricity.	1
The UK government plans to phase out coal-fired power stations to reduce CO emissions.	2
Electricity demand varies throughout the day – non-renewables are used to meet peak demand because they are controllable.	3
Renewables are increasingly replacing non-renewables as technology improves and costs fall.	4

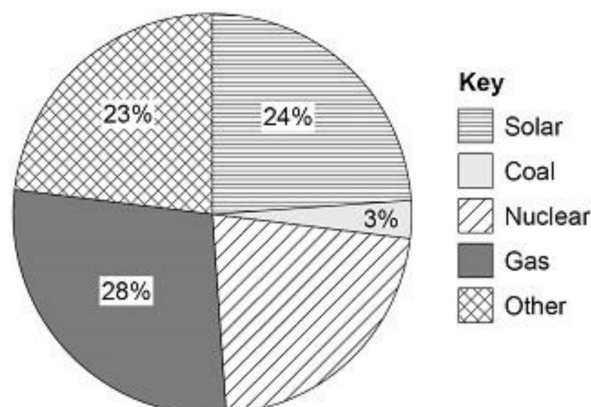


Fig 11.1 – UK electricity generation by source on one day in June 2018 (solar, coal, nuclear, gas, other).

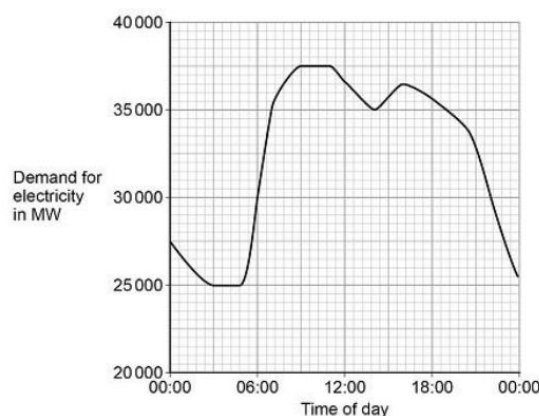


Fig 11.2 – Electricity demand (MW) varying through the day in the UK.

Exam Question [8 marks]

Figure 11.1 shows how different energy resources generated electricity in the UK on one day in June 2018.

- | | |
|---|-----|
| (a) The UK government plans to stop using coal-fired power stations by 2025. Explain one environmental problem caused when electricity is generated by burning coal. | (2) |
| (b) Use Figure 11.1 to determine the percentage of electricity generated by nuclear power that day. | (2) |
| (c) Figure 11.2 shows electricity demand varies with time of day. Identify the maximum and minimum demand and calculate the difference. | (2) |
| (d) Explain why non-renewable sources are used to meet peak electricity demand. | (2) |

Mark Scheme

- (a)** CO is a greenhouse gas contributing to climate change; SO causes acid rain/respiratory problems.
- (b)** Nuclear = 22% (approximately; from the pie chart, the hatched sector).
- (c)** Max $\approx$ 37500 MW; min $\approx$ 22000 MW; difference $\approx$ 15500 MW.
- (d)** Non-renewables can be turned up quickly to match demand; renewables depend on weather.

LESSON 12

Renewable Energy Resources

Do Now

1. What is a renewable energy resource?

One that is naturally replenished and will not run out.

2. Name three renewable energy resources.

Any three: solar, wind, hydroelectric, tidal, wave, geothermal, biofuels.

3. What is one disadvantage of wind power?

Only works when wind is blowing; unreliable.

4. Approximately how long will fossil fuels last at current usage?

Approximately 50 years.

Part 1 of 3: Wind, Solar & Geothermal

Wind power: Wind turns turbine blades generator electricity. Zero emissions, renewable. Disadvantage: intermittent; visual impact; harms birds.	1
Solar power: Photovoltaic cells convert sunlight to electricity. Renewable, no emissions. Disadvantage: no output at night or in cloudy weather; requires large area.	2
Geothermal: Water pumped into hot rocks underground, returns as steam drives turbine. Renewable, no emissions. Disadvantage: only available in geologically active areas.	3

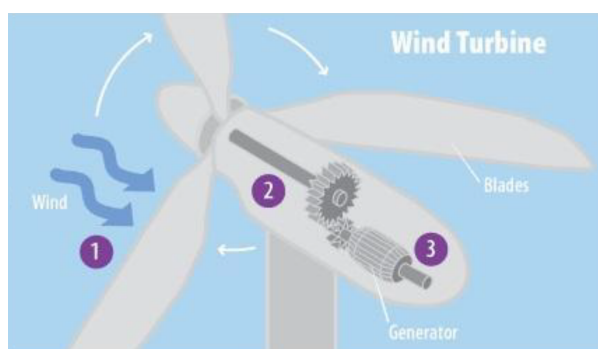


Fig 12.1 – Wind turbine: (1) wind rotates blades, (2) gearbox speeds up rotation, (3) generator produces electricity.

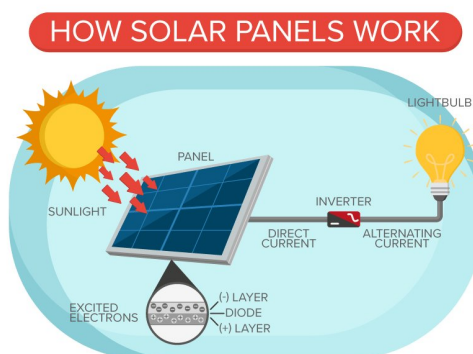


Fig 12.2 – How a solar panel works: sunlight excites electrons in photovoltaic cells (negative layer diode positive layer), generating direct current (DC); an inverter converts DC to alternating current (AC) for use in the

home.

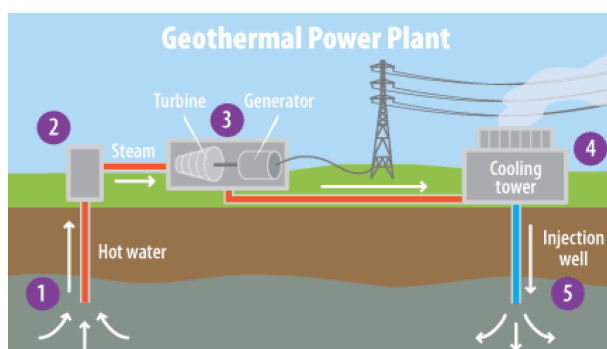


Fig 12.3 – Geothermal power plant: (1) cold water injected, (2) steam rises, (3) turbine, (4) cooling tower, (5) injection well.

Questions

1. Explain how wind power generates electricity.	(3)
2. Give one advantage and one disadvantage of solar power.	(2)
3. Why is geothermal power only available in certain locations?	(2)
4. A wind turbine generates 2 MW of power. How much energy does it produce in 1 hour?	(3)

Answers

1. Wind turns turbine blades attached to a generator; rotation of the generator produces electricity.
2. Adv. renewable/no emissions. Disadv. only works in sunlight/weather-dependent.
3. It requires high underground temperatures close to the surface (volcanic/tectonic regions).
4. $E = 2 \times 10^6 \times 3600 = 7.2 \times 10^9 \text{ J} = 7200 \text{ MJ}$.

Part 2 of 3: Hydroelectric, Tidal & Wave

Hydroelectric: Water in reservoir flows through turbines. Renewable, zero emissions, reliable. Disadvantage: habitat destruction; needs suitable geography.	1
Tidal power: Turbines in sea turn with incoming/outgoing tides. Renewable, predictable. Disadvantage: few suitable sites; affects marine life.	2
Wave power: Floating devices harness wave motion to drive generators. Renewable. Disadvantage: unreliable, easily damaged by storms.	3

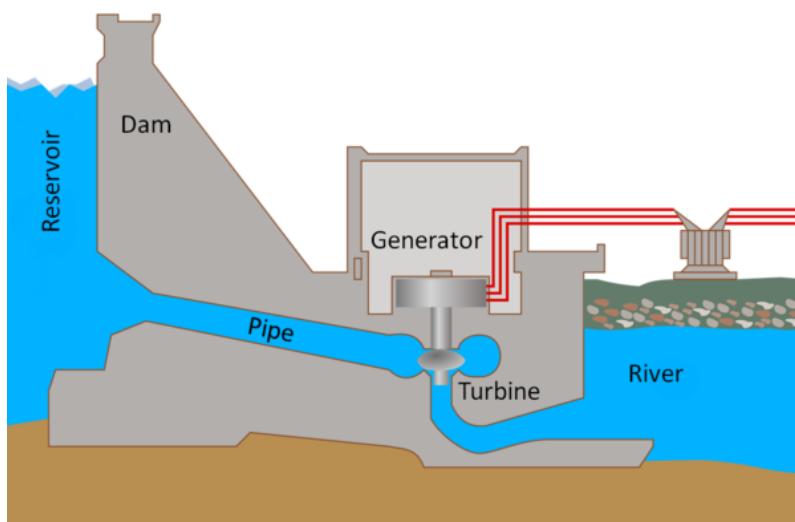


Fig 12.4 – Hydroelectric dam: reservoir penstock turbine generator power lines.

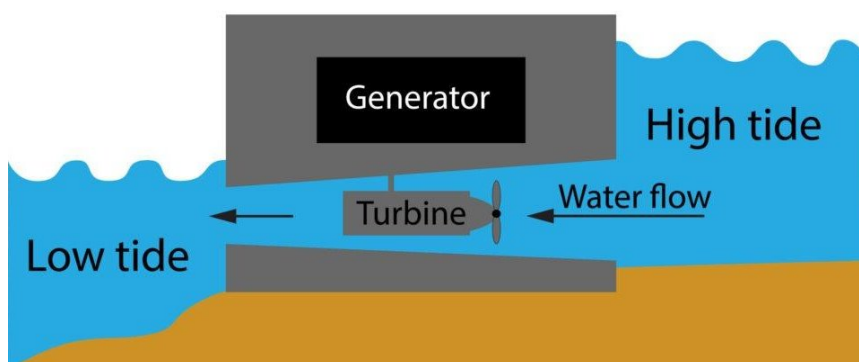


Fig 12.5 – Tidal power: water flows from high tide to low tide, passing through a turbine connected to a generator; the direction of water flow reverses with each tide, so the turbine generates electricity on both the incoming and outgoing tides.

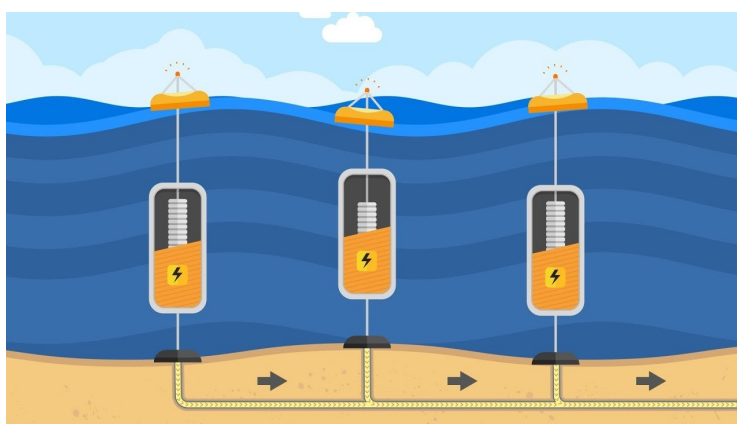


Fig 12.6 – Wave power: surface buoys rise and fall with ocean waves, driving a linear generator submerged beneath each device; the electricity produced is carried to shore via undersea cables.

Questions

1. Describe how a hydroelectric power station generates electricity.	(3)
2. Give one advantage of tidal power over wind power.	(1)
3. Why might wave power be unreliable?	(2)
4. What environmental problem is associated with hydroelectric dams?	(2)

Answers

1. Water flows from reservoir through penstocks turbines generator electricity.
2. Tides are predictable (unlike wind), so output can be planned in advance.
3. Wave height varies with weather; storms can damage equipment.
4. Damming floods land/habitat; disrupts river ecosystems and fish migration.

Part 3 of 3: Biofuels & Global Energy Trends

Biofuels (wood, bioethanol, manure) are produced from living things and are considered renewable.	1
Biofuels are carbon-neutral in theory (CO absorbed growing = CO released burning), but in practice still contribute to climate change.	2
Disadvantage: land used for biofuel crops cannot grow food – a concern where food shortages exist.	3
Global primary energy consumption has risen sharply since 1800, driven by industrialisation and population growth.	4
Renewables are a small but growing fraction; fossil fuels still dominate globally.	5

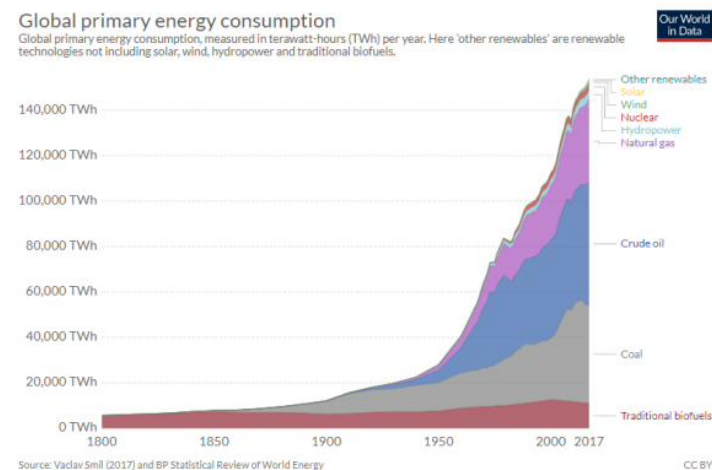


Fig 12.4 – Global primary energy consumption (TWh/year) since 1800. Coal, crude oil and gas dominate; renewables are rising rapidly.

Questions	
1. Why are biofuels considered renewable?	(2)
2. Give one reason why biofuels are not completely carbon-neutral in practice.	(2)
3. From Fig 12.4, when did global energy use begin to increase most rapidly?	(1)
4. What was the main cause of the rapid energy use increase after 1950?	(2)
5. How has the use of renewables compared to non-renewables changed? Give two differences.	(4)

Answers

1. They come from living organisms that can be regrown/replenished.
2. Land-use changes (deforestation) and transport/processing release extra CO.
3. After approximately 1950.
4. Industrialisation and population growth dramatically increased energy demand.
5. Non-renewables still far larger in total; renewables growing faster proportionally; non-renewables dominated for most of history.

Exam Question [6 marks]

An electric car has a motor powered by a battery. A diesel car has an engine powered by diesel fuel.

(a) The table compares the two cars. State one way the electric car is better for the environment.	(1)
(b) Electricity is generated in a gas power station (efficiency 0.35) and transmitted to the electric car (transmission efficiency 0.90). Calculate the overall efficiency of generating and transmitting the electricity.	(3)
(c) Give one reason why renewable energy sources are important for the future.	(2)

Mark Scheme

- (a) The electric car produces no direct CO/pollution emissions during use.
- (b) Overall efficiency = $0.35 \times 0.90 = 0.315 = 31.5\%$.
- (c) Fossil fuels will run out / to reduce CO emissions and combat climate change.