IGCSE PHYSICS 0625 · CHAPTER 4 NOTES · ~11 MIN READ

Energy, work & power

Where energy is stored, how it moves, how fast, and how much is wasted — plus every energy resource you may be asked to compare.

Energy stores & transfers | Conservation of energy | Kinetic & gravitational energy | Work done | Power | Efficiency & Sankey diagrams | Energy resources

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No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- Energy is never created or destroyed. It is **transferred** between stores, and some always ends up as wasted thermal energy.
- **Work done = force × distance** (in joules). Work done = energy transferred.
- **Power = work ÷ time** (in watts) — how fast energy is transferred.
- EXT **$E_k = \frac{1}{2}mv^2$**, **$\Delta E_p = mg\Delta h$** and **efficiency = useful ÷ total × 100%**.

BY THE END YOU CAN

- Name the energy stores and the four ways energy is transferred.
- Use W = Fd and P = W ÷ t.
- Calculate kinetic energy and changes in gravitational energy. EXT
- Read a Sankey diagram and calculate efficiency. EXT
- Compare the energy resources, renewable and non-renewable.

1 Energy stores and transfers

The energy stores

Store	Example
kinetic	a moving car, a falling ball
gravitational potential	a book on a shelf, water behind a dam
chemical	food, fuel, a battery
elastic (strain)	a stretched spring or elastic band
nuclear	uranium, the core of the Sun
electrostatic	separated charges, a charged balloon
internal (thermal)	the moving particles in a hot object

Four ways energy is transferred

Transfer	What happens
by a force (work done)	a force moves something
electrically	a current flows round a circuit
by heating	thermal energy moves from hot to cold (conduction, convection, radiation)
by waves	light and sound carry energy away from a source

Conservation of energy — energy is never created or destroyed — the total energy before always equals the total energy after.

- Example flow: phone battery → **chemical → electrical → light + sound + thermal (wasted)**.
- **Dissipated** energy spreads out into the surroundings as thermal energy. It still exists, but it is too spread out to use again.

PICTURE IT

A lamp warms the room by a tiny amount. All that energy is still there, but you cannot gather it back into the lamp.

COMMON MISTAKE

"The energy is used up." Energy is never used up — it ends up in stores that are not useful.

Kinetic and gravitational energy

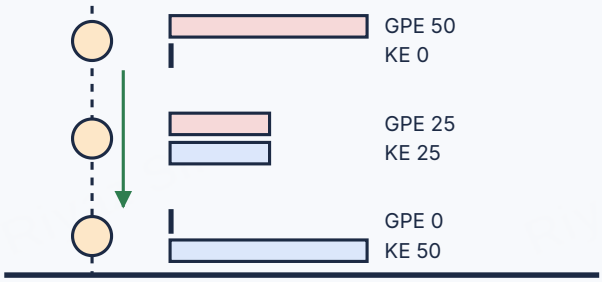
EXTENDED

$$E_k = \tfrac{1}{2}\, m\, v^2$$

kinetic energy (J) = ½ × mass (kg) × speed² (m/s)²

$$\Delta E_p = m\, g\, \Delta h$$

change in gravitational potential energy (J) = mass × g × change in height (m)



energy converted — the total stays 50

A ball falls: gravitational energy turns into kinetic energy. At every height the two add up to the same total (50 units).

WORKED EXAMPLE

EXT **A 2.0 kg ball is dropped from 5.0 m. Find its speed just before it lands. (g = 9.8 N/kg, ignore air resistance)**

1. Loss in GPE = mgΔh = 2.0 × 9.8 × 5.0 = 98 J
2. All of it becomes kinetic energy: ½ × 2.0 × v² = 98
3. **v² = 98, so v = 9.9 m/s**

WORKED EXAMPLE

EXT **Find the kinetic energy of a 1200 kg car travelling at 15 m/s.**

1. $E_k = \tfrac{1}{2}mv^2 = \tfrac{1}{2} \times 1200 \times 15^2$
2. = ½ × 1200 × 225
3. **= 135 000 J (135 kJ)**

EXAM TIP

Doubling the speed makes the kinetic energy **four times** bigger, because v is squared. That is why fast crashes are so much more damaging.

COMMON MISTAKE

Forgetting to square the speed.

2 Work and power

Work done

Work done — the energy transferred when a force moves an object.

$$W = F\,d$$

work done (J) = force (N) × distance moved in the direction of the force (m)

- 1 joule (J) is the work done when a force of 1 N moves an object 1 m.
- Work done always equals energy transferred: **W = ΔE**.

WORKED EXAMPLE

A person pushes a crate with a force of 50 N for 4.0 m. Find the work done. Where does the energy go?

1. W = Fd = 50 × 4.0
2. = **200 J**
3. **The energy becomes kinetic energy of the crate and, because of friction, thermal energy of the floor and crate**

WORKED EXAMPLE

A crane lifts a 20 kg box through 3.0 m. Find the work done. (g = 10 N/kg)

1. To lift at steady speed, force = weight = mg = 20 × 10 = 200 N
2. W = Fd = 200 × 3.0
3. = **600 J**
4. **This is stored as gravitational potential energy**

Power

Power — how fast work is done, or energy is transferred.

$$P = \frac{W}{t} = \frac{\Delta E}{t}$$

power (W) = work done (J) ÷ time (s) = energy transferred (J) ÷ time (s)

- 1 watt (W) = 1 joule per second. 1 kW = 1000 W; 1 MW = 1 000 000 W.

PICTURE IT

Two people carry the same box up the same stairs. The work done is the same, but the one who does it faster has more power.

WORKED EXAMPLE

A 60 kg student runs up stairs 3.0 m high in 5.0 s. Find the power. (g = 10 N/kg)

1. Work done = mgΔh = 60 × 10 × 3.0 = 1800 J
2. P = W ÷ t = 1800 ÷ 5.0
3. **= 360 W**

COMMON MISTAKE

Mixing up joules and watts. A 100 W lamp transfers 100 **J every second**.

3 Efficiency and Sankey diagrams

Wasted energy

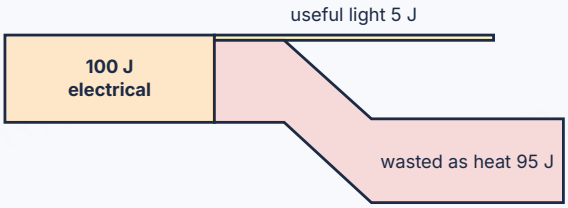
- In nearly every device some energy is wasted, mostly as thermal energy (and sometimes as sound).
- **More efficient** means more of the input energy is turned into the useful output.
- Improve efficiency by reducing friction (lubricants), insulating (to stop heat loss), and streamlining (to cut air resistance).

EXT $$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

always less than 100%

EXT $$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}} \times 100\%$$

the same idea with power



efficiency = 5 ÷ 100 × 100% = 5%
band width = amount of energy

A Sankey diagram. The width of each band shows the amount of energy. A filament lamp turns only 5 J of every 100 J into light and wastes 95 J as heat.

WORKED EXAMPLE

EXT **A motor takes in 500 J of electrical energy and lifts a load, gaining 350 J of gravitational energy. Find the efficiency.**

1. efficiency = useful output ÷ total input × 100%
2. = 350 ÷ 500 × 100%
3. = **70%**
4. **The other 150 J is wasted as thermal energy and sound**

WORKED EXAMPLE

EXT **A power station takes in 100 MJ of chemical energy from fuel and delivers 40 MJ of electrical energy. Find the efficiency and the wasted energy.**

1. efficiency = 40 ÷ 100 × 100% = **40%**
2. **wasted = 100 − 40 = 60 MJ**

- EXT In a multi-stage process (fuel → boiler → turbine → generator) energy is wasted at **every** stage. Total in = total useful out + all the wasted energy.

COMMON MISTAKE

Efficiency above 100%. That would mean creating energy, which is impossible.

4 Energy resources

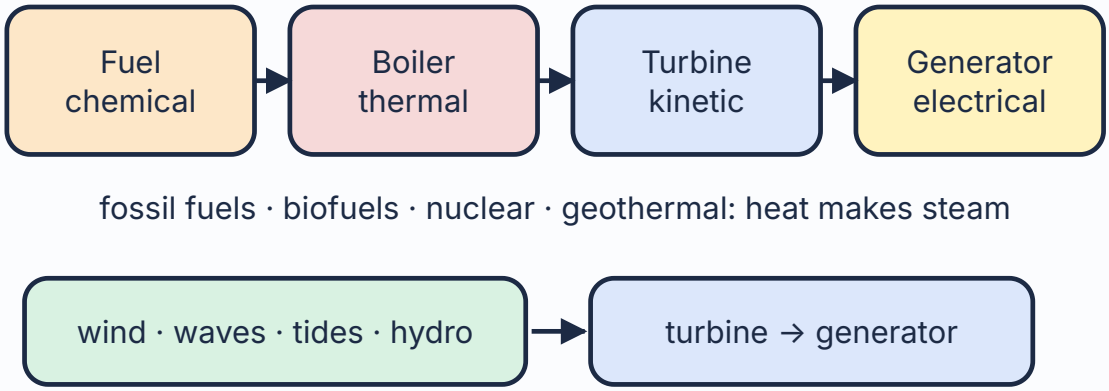
Renewable and non-renewable

Renewable — replaced as fast as we use it, so it will not run out.

Non-renewable — a finite supply that cannot be replaced in a human lifetime.

Resource	Type	Advantage	Disadvantage
coal, oil, gas	non-renewable	cheap, reliable, easy to switch on	releases CO_2, causes acid rain, will run out
nuclear fission	non-renewable	no CO_2, a lot of energy from a little fuel	radioactive waste, accident risk, costly to build and close
wind	renewable	no fuel cost, no pollution	not always windy, noisy, spoils views
hydroelectric	renewable	reliable, no fuel, can store water	floods land and destroys habitats, costly to build
waves and tides	renewable	no fuel cost, tides are predictable	costly, can harm marine life, hard to build
geothermal	renewable	reliable, low CO_2	only practical in volcanic regions
solar cells and panels	renewable	no pollution, good for remote places	only works in daylight, depends on weather
biofuels	renewable	can be regrown, plants absorb the CO_2 released	needs farmland, still releases CO_2 when burned

- Solar **cells** make electricity directly. Solar **panels** heat water.



Most power stations share one chain. A fuel makes steam, the steam turns a turbine, and the turbine spins a generator. Wind, waves, tides and hydro skip the boiler. Solar cells skip the turbine too.

- Compare resources on: renewable or not, how available, how **reliable**, the scale of power, and the environmental impact.

EXAM TIP

In a "discuss" question give one advantage AND one disadvantage, and compare reliability. Wind and solar depend on the weather. Fossil fuels and hydro can be switched on when needed.

The Sun's role

EXTENDED

- The Sun is the main source of energy for almost every resource: fossil fuels (ancient plants stored sunlight), wind (the Sun heats the air), waves, hydroelectric (the Sun evaporates water), biofuels and solar. **Exceptions: geothermal, nuclear and tidal.**
- The Sun releases energy by **nuclear fusion** — hydrogen nuclei join to make helium. See the stars and Universe chapter.
- Researchers are working on fusion power stations on Earth. Fusion has not yet been used for large-scale electricity.

5 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. Name the four ways energy can be transferred.
2. How much work does a force of 30 N do moving a box 5.0 m?
3. A motor does 4800 J of work in 60 s. What is its power?
4. Which are renewable: coal, wind, uranium, solar?
5. Find the kinetic energy of a 0.50 kg ball at 4.0 m/s.
6. Why can no device be 100% efficient?

EXAM-STYLE

7. A 0.50 kg ball is thrown straight up at 12 m/s. Find the maximum height. (g = 10 N/kg, ignore air resistance)
8. A lift motor does 24 000 J of useful work in 8.0 s. Its input power is 4.0 kW. Find the efficiency.
9. A 1000 kg car slows from 20 m/s to rest. How much kinetic energy is transferred, and to what store?
10. Give one advantage and one disadvantage of generating electricity from nuclear fission. [2]

Show answers

1. by a force (work), electrically, by heating, by waves
2. 30 × 5.0 = 150 J
3. 4800 ÷ 60 = 80 W
4. wind and solar
5. ½ × 0.50 × 4.0^2 = 4.0 J EXT
6. Some energy is always wasted, usually as thermal energy spreading into the surroundings.
7. Ek at launch = ½ × 0.50 × 12^2 = 36 J
   all of it becomes GPE: mgh = 0.50 × 10 × h = 36
   h = 36 ÷ 5.0 = 7.2 m
8. useful power = 24 000 ÷ 8.0 = 3000 W
   efficiency = 3000 ÷ 4000 × 100% = 75%
9. Ek = ½ × 1000 × 20^2 = 200 000 J
   transferred to thermal (internal) energy in the brakes, tyres and surroundings
10. Advantage: no carbon dioxide is produced / a lot of energy from a little fuel
    Disadvantage: radioactive waste stays dangerous for a long time / risk of an accident

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