A-LEVEL PHYSICS • EXERCISE SHEET

5.1 Energy conservation

Name: _____ Class: _____ Date: _____ **Total: 26 marks**

KEY WORDS power 功率 • work 功 • efficiency 效率 • energy 能量 • conservation of energy 能量守恒

Objective

Build the skills to answer exam questions on **energy conservation** — work, the conservation principle, efficiency and power.

You must be able to:

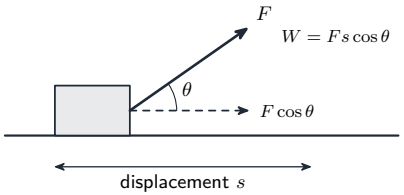
- use **work done** $= Fs\cos\theta$
- apply **conservation of energy** (e.g. GPE → KE)
- use **efficiency** and **power** ($P = W/t$ and $P = Fv$)

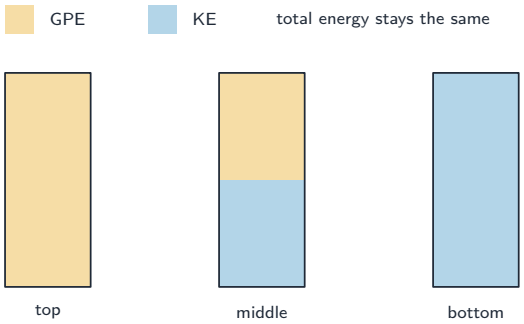
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Work done

Work is done when a force moves along its own line: $W = Fs\cos\theta$. Only the component **along** the displacement does work:





Energy is conserved as it transfers

- $\theta = 0$: $W = Fs$ (max); $\theta = 90°$: $W = 0$ (e.g. the normal force on a flat road); $\theta = 180°$: $W = -Fs$ (e.g. friction).

■ Conservation of energy

Energy is never made or destroyed. On a **smooth** ramp, GPE → KE:

$$mgh = \tfrac{1}{2}mv^2 \Rightarrow v = \sqrt{2gh}.$$

■ Efficiency and power

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{total energy in}}, \qquad P = \frac{W}{t}, \qquad P = Fv.$$

$P = Fv$ comes from $P = W/t = Fs/t = F(s/t) = Fv$.

■ Efficiency, and where the wasted energy goes

Efficiency compares what you **want** with what you **paid for**, as energies or as powers:

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} = \frac{\text{useful power output}}{\text{total power input}}$$

It has **no unit**, and it can be written as a decimal or a percentage — but never above 1. Two habits win the marks:

- **Work out the useful output first**, from what the machine actually achieves (mgh for a lift, Fs for a drag, $\frac{1}{2}mv^2$ for a launch).
- **The wasted energy is input minus useful output**, and the exam wants to know *where it went*: thermal energy in the motor windings and bearings, sound, and in a lift the kinetic energy left over if it does not stop.

Worked example. A pump raises 600 kg of water through 12 m in 30 s, drawing 3.0 kW.

$$P_{\text{useful}} = \frac{mgh}{t} = \frac{600 \times 9.81 \times 12}{30} = 2354 \text{ W}, \qquad \text{efficiency} = \frac{2354}{3000} = 0.78$$

2 Practice

Now apply the methods above.

2.1 Define the **work done** by a force. [1]

2.2 A child pulls a sledge 5.0 m with a 20 N force at 60° to the ground. Find the **work done**. [2]

2.3 Define **power** and give its unit. [1]

2.4 State the **principle of conservation of energy**. [1]

3 Exam-style questions

3.1 A force acts at 90° to the direction of motion. The work it does is: [1]

A B
C D

A maximum
B Fs
C zero
D negative

3.2 A ball is released from rest at the top of a **smooth** ramp 1.2 m high. Calculate its speed at the bottom. ($g = 9.81$ m s^{-2}.) [3]

3.3 A motor lifts a 50 kg load through 8.0 m in 10 s.

(a) Calculate the **useful power** output. [2]

(b) If the input power is 500 W, calculate the **efficiency**. [2]

3.4 Derive $P = Fv$ from $P = W/t$. [2]

3.5 A crane is used on a building site.

(a) **Define** the **work done** by a force. [1]

(b) A block of mass m is raised vertically at constant speed through a height Δh. **Derive** an expression, in terms of m and Δh, for the change in gravitational potential energy ΔE_{P} of the block. State the meaning of any other symbol you use. [2]

(c) The crane raises a steel beam of mass 450 kg at constant speed through a vertical height of 24 m, taking 40 s.

(i) **Calculate** the work done on the beam. [2]

(ii) **Calculate** the useful output power of the crane. [2]

(iii) The input power to the crane is 3.6 kW. **Calculate** its efficiency. [2]

(iv) **Determine** the energy wasted during the 40 s, and **state** one form it takes. [2]