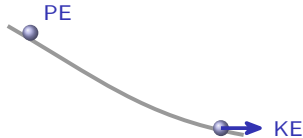


Work, Energy, and Power

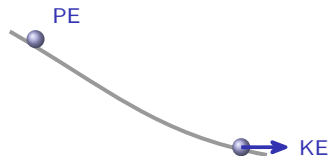
AP Physics 1 ■ Unit 3

AP Physics 1



What we will cover

- 1 Kinetic energy and the work-energy theorem
- 2 Work
- 3 Potential energy
- 4 Conservation of energy
- 5 Power





Kinetic energy and the work-energy theorem

Energy of motion

$$KE = \frac{1}{2}mv^2$$

A **scalar**. Depends on v^2 – double the speed, **quadruple** the energy.

Work-energy theorem

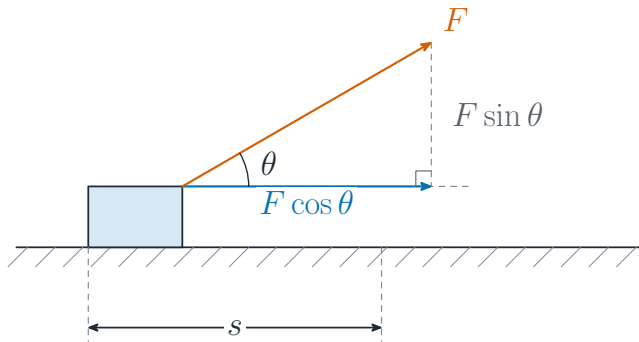
$$W_{net} = \Delta KE$$

Kinetic energy links force to motion:

- positive net work $\Rightarrow$ speeds up
- negative net work $\Rightarrow$ slows down

2 kg from 3 $\rightarrow$ 5 m/s: KE rises 9 $\rightarrow$ 25 J, so $W_{net} = 16$ J.

Only the force component along the displacement



Only the force component along the displacement does work



Work

Energy transferred by a force

$$W = Fd \cos \theta$$

The angle θ sets the sign:

- along the motion (0°) – **positive**
- against it (180°) – **negative**
- perpendicular (90°) – **zero**

A changing force: work = area under an F - x graph.



Power is the rate of energy transfer



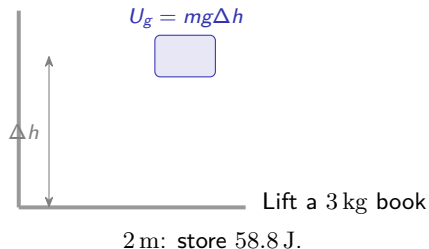
Potential energy

Potential energy is stored in an arrangement – it depends on **position**, not motion.

Two common kinds

$$\Delta U_g = mg\Delta h \quad U_s = \frac{1}{2}kx^2$$

A **conservative force** (gravity, spring): its work depends only on start and end.





Conservation of energy

Total energy is conserved – it only changes form.

- conservative forces keep **mechanical energy** $KE + U$ constant
- friction turns it into **thermal energy** (still conserved overall)

Drop 1 kg from 5 m: 49 J of $U_g \rightarrow KE$, so $v \approx 9.9$ m/s.



Mechanical energy trades kinetic and potential



Power

Power is how **fast** energy is transferred:

Two forms

$$P = \frac{W}{\Delta t} \quad P = Fv$$

Measured in **watts** (joules per second).

Same work, more power = done **sooner**.

Worked example

Lift 50 kg up 10 m in 5 s:

$$W = mgh = 4900 \text{ J}$$

$$P = \frac{4900}{5} = 980 \text{ W}$$

In 2 s instead: 2450 W – same work, more power.

The general potential energy, and efficiency

near a surface

$U_g = mgh$ – valid only where g is roughly constant

in general

for two spherical masses a distance r apart, $U_g = -\frac{Gm_1 m_2}{r}$, taking zero at infinity

why negative

the system is **bound**: energy must be added to separate the masses

elastic potential energy

$U_s = \frac{1}{2} kx^2$, from natural length

total mechanical energy

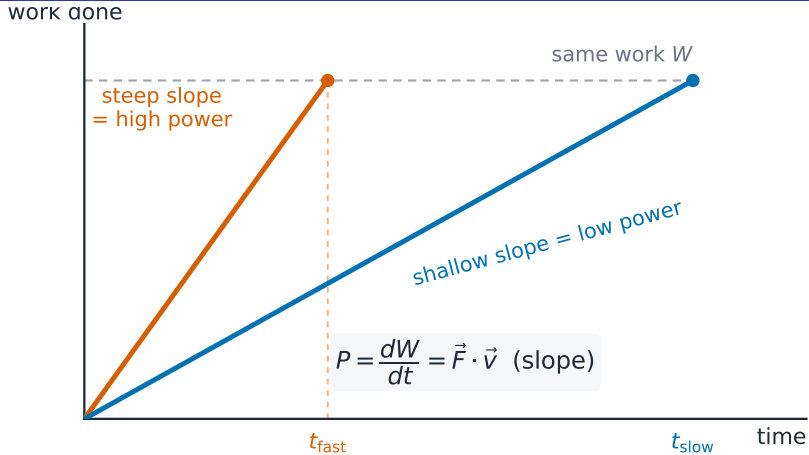
$E = K + U$; conserved when only conservative forces act

efficiency

useful output power divided by total input power – real machines always waste some

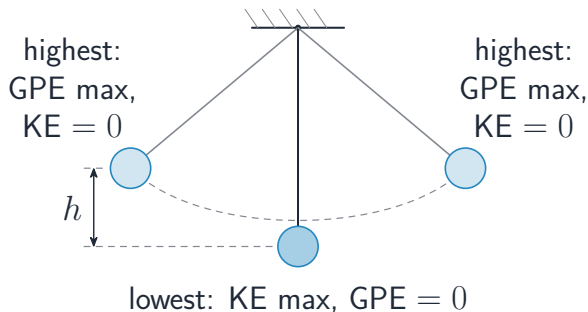
The **work–energy theorem** $W_{\text{net}} = \Delta K$ is the bridge between the two halves of this unit. Quote it when a question gives a force and asks for a speed.

Power is the slope of the work-time graph



Power is the slope of the work-time graph: the same work in less time means more power

Conservation of Energy, continued



A swinging pendulum trades gravitational potential energy for kinetic energy and back

Exam tips

- Use $W = Fd \cos \theta$: work is zero when the force is perpendicular to the motion, and negative when it opposes it.
- Reach for the **work–energy theorem** ($W_{\text{net}} = \Delta K$) or **energy conservation** ($K_1 + U_1 = K_2 + U_2$) instead of forces whenever the path is complicated.
- When friction acts, mechanical energy is **not** conserved – subtract the energy lost to heat.
- Remember $K \propto v^2$: doubling the speed **quadruples** the kinetic energy (and the stopping distance).
- Use $P = Fv$ for power at a steady speed; at constant velocity the net force is zero but the power is **not**.



Unit 3 – key takeaways

1

Work

$W = Fd \cos \theta$; area under an F - x graph

2

Kinetic energy

$KE = \frac{1}{2}mv^2$; net work equals ΔKE

3

Potential energy

$mg\Delta h$ and $\frac{1}{2}kx^2$ from conservative forces

4

Conservation

$KE + U$ constant; friction makes heat; $P = W/\Delta t$

Check yourself

- 1 Double an object's speed – what happens to its KE ?
- 2 Carrying a bag horizontally – how much work on the bag?
- 3 Friction acts. Is mechanical energy conserved?
- 4 Two motors, same lift, one twice as fast – compare power.



Answers 1. it quadruples 2. zero (force $\perp$ motion) 3. no – some becomes heat
4. twice the power