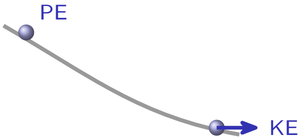
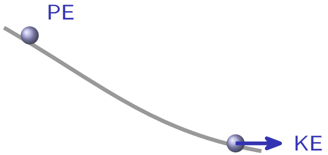
Work, Energy, and Power

AP Physics 1 ▪ Unit 3

AP Physics 1



What we will cover



1 Kinetic energy

Kinetic energy and the work-energy theorem

Energy of motion

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

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

Work-energy theorem

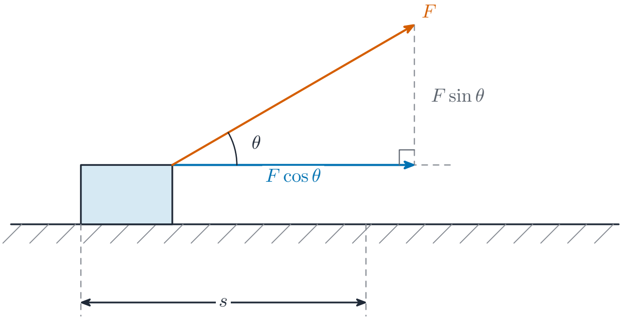
$$W_{net} = \Delta KE$$

Kinetic energy 动能 links force to motion:

- positive net work ⇒ speeds up
- negative net work ⇒ slows down

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

Only the force component along the displacement



Only the force component along the displacement does work

2 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

3 Potential energy

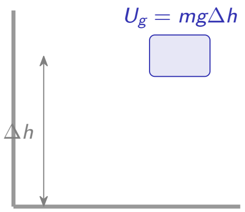
Potential energy

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

Two common kinds

$$\Delta U_g = mg\,\Delta h \qquad U_s = \tfrac{1}{2}kx^2$$

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



Lift a $3\,\mathrm{kg}$ book $2\,\mathrm{m}$: store $58.8\,\mathrm{J}$.

4 Conservation

Conservation of energy

Total energy 能量守恒定律 is conserved – it only changes form.

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

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

Mechanical energy trades kinetic and potential

5 Power

Power

Power 功率 is how fast energy is transferred:

Two forms

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

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

> Same work, more power = done sooner.

Worked example

Lift $50\,\mathrm{kg}$ up $10\,\mathrm{m}$ in $5\,\mathrm{s}$:

$$W = mgh = 4900\,\mathrm{J}$$

$$P = \tfrac{4900}{5} = 980\,\mathrm{W}$$

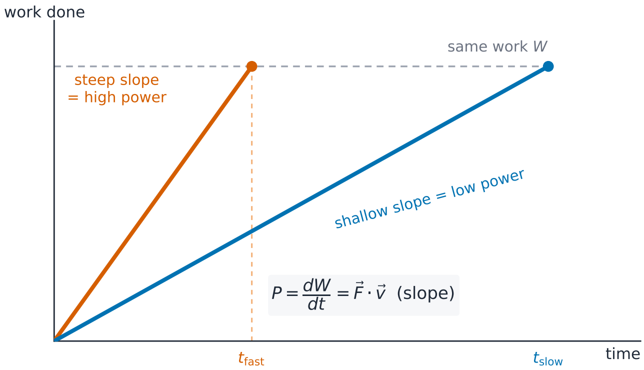
In $2\,\mathrm{s}$ instead: $2450\,\mathrm{W}$ – same work, more power.

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, $U_g = -\dfrac{Gm_1 m_2}{r}$, taking zero at infinity
why negative	the system is bound: energy must be added to separate the masses
elastic potential energy 弹性势能	$U_s = \frac{1}{2}kx^2$, from natural length
total mechanical energy 总机械能	$E = K + U$; conserved when only conservative forces act
efficiency 效率	useful output power divided by total input power – real machines always waste some

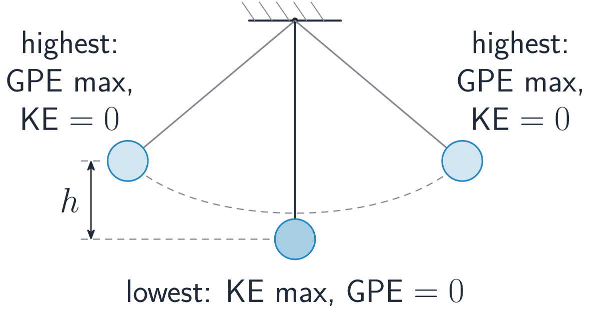
The **work–energy theorem** 动能定理 $W_{\text{net}} = \Delta K$ is the bridge between the two halves of this unit. Quote it when a question gives a force and asks for a speed.

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**.

6 Recap

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

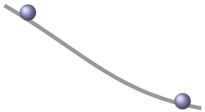
$mg\Delta h$ and $\frac{1}{2}kx^2$ from conservative forces

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