

Energy conservation, bar charts and power

AP Physics 1 (algebra-based) · Lesson

Quick answer: Conservation of energy says the total energy of an isolated system stays constant: energy changes form, such as gravitational or spring potential energy becoming kinetic energy, but is never created or destroyed. Power measures how quickly energy is transferred, $P = \Delta E/t$, and is measured in watts (joules per second).

Level: AP Physics 1 (algebra-based) · **Curriculum:** AP P1 Unit 3

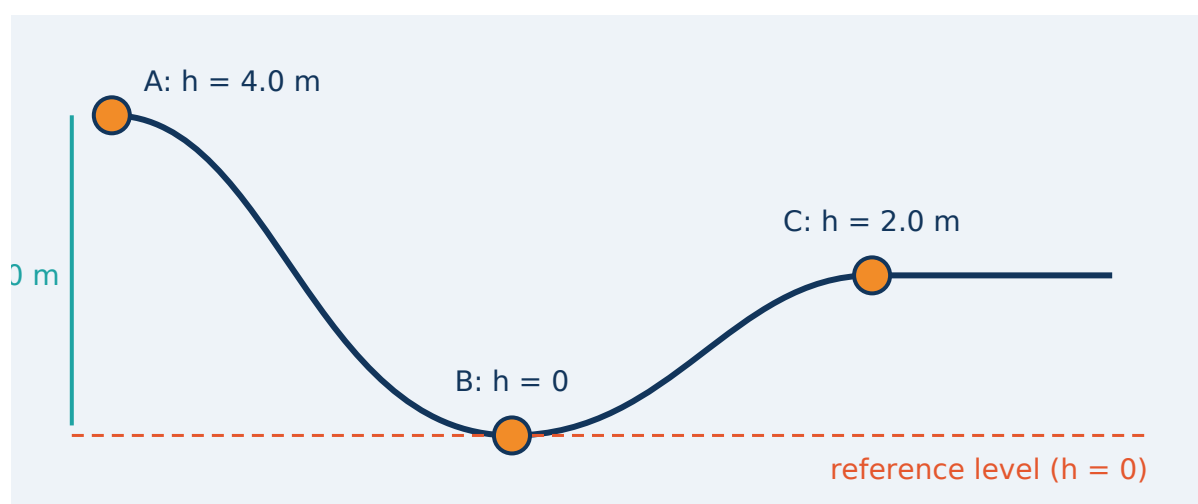
What is potential energy?

Kinetic energy belongs to motion. Potential energy belongs to the arrangement of a system: how far apart its interacting parts are. A raised crate, a stretched catapult band and a squeezed bicycle-pump spring all store energy that can later turn into motion.

Definition

Potential energy is energy stored in the configuration of a system of interacting objects. Near Earth's surface the gravitational form is $U_g = mgh$, where h is the height above a reference level that you choose. An ideal spring stores $U_s = \frac{1}{2}kx^2$, where x is the stretch or compression from the relaxed length. Both are measured in joules (J).

Only changes in potential energy matter, so you may put the reference level wherever is convenient, usually the lowest point of the motion. Figure 1 shows a track with three marked points; if the reference level is moved, every value of U shifts by the same amount.



Heights are measured upward from the chosen reference level. Only differences in height change the stored energy.

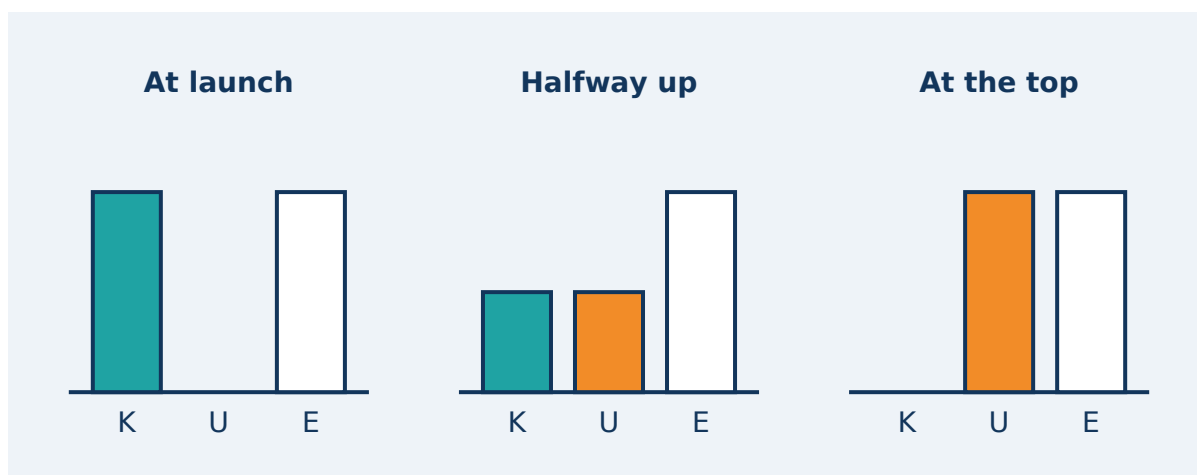
How does conservation of energy work?

A system is the group of objects you decide to track. If nothing outside the system does work on it, and no friction turns motion into thermal energy, the mechanical energy $K + U$ stays constant. When an outside force does work W_{ext} , or friction heats the surfaces, you must add these terms to the account.

Key law

$K_1 + U_1 + W_{\text{ext}} = K_2 + U_2 + \Delta E_{\text{int}}$. Here $K = \frac{1}{2}mv^2$, W_{ext} is the work done on the system by outside forces, and ΔE_{int} is the increase in internal (thermal) energy. For sliding friction, $\Delta E_{\text{int}} = f_k d$.

An energy bar chart turns this law into a picture. Each bar is a store of energy drawn in equal units, and the total must balance between the first state and the last.



Bars show kinetic energy K , gravitational potential energy U and total mechanical energy E . The total bar never changes.

Worked example 1

Diego in Texas (60 kg with his board) starts from rest at the top of a smooth skate ramp 2.5 m high. Find his speed at the bottom.

Method: take the bottom as $h = 0$. Then $U_1 = mgh$ and $K_2 = \frac{1}{2}mv^2$, so $mgh = \frac{1}{2}mv^2$ and the mass cancels. $v = \sqrt{2gh} = \sqrt{(2 \times 9.81 \text{ m/s}^2 \times 2.5 \text{ m})} = \sqrt{49.05} = \mathbf{7.0 \text{ m/s}}$.

Worked example 2

Chiamaka in Lagos compresses a spring ($k = 250 \text{ N/m}$) by 0.12 m against a 0.40 kg block on a smooth table, then releases it. Find the block's speed as it leaves the spring.

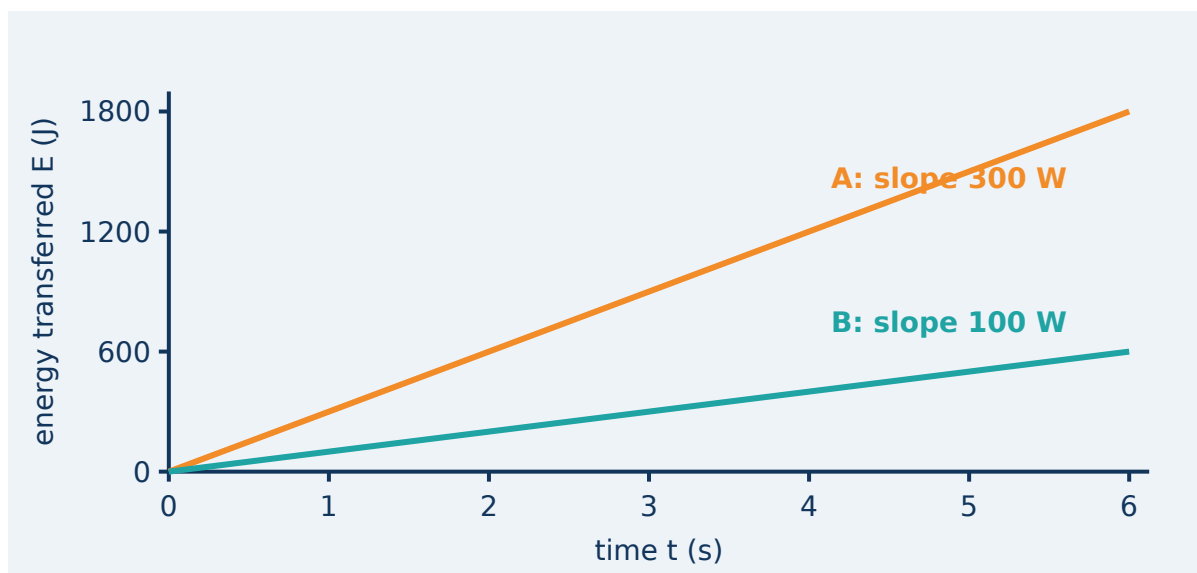
Method: $U_s = \frac{1}{2}kx^2 = \frac{1}{2} \times 250 \text{ N/m} \times (0.12 \text{ m})^2 = 1.8 \text{ J}$. All of it becomes kinetic energy, so $\frac{1}{2}mv^2 = 1.8 \text{ J}$ and $v = \sqrt{(2 \times 1.8 \text{ J} \div 0.40 \text{ kg})} = \sqrt{9.0} = \mathbf{3.0 \text{ m/s}}$.

What is power and how do you calculate it?

Definition

Power is the rate at which energy is transferred, or at which work is done. Average power is $P = \Delta E/t = W/t$. When a constant force F acts on an object moving with velocity v , the instantaneous power is $P = Fv \cos\theta$, where θ is the angle between force and velocity. The SI unit is the watt: $1 \text{ W} = 1 \text{ J/s}$.

Two machines can do the same job yet differ in power: the stronger one finishes sooner. Figure 3 compares them; the steeper line is the more powerful machine.



The slope of an energy-time graph is the power. A steeper line means energy is transferred faster.

Worked example 3

An electric hoist lifts an 80 kg load at a steady 0.50 m/s. Find the useful power it delivers.

Method: the lifting force equals the weight, $F = mg = 80 \text{ kg} \times 9.81 \text{ N/kg} = 784.8 \text{ N}$, and it points along the motion ($\cos 0^\circ = 1$). $P = Fv = 784.8 \text{ N} \times 0.50 \text{ m/s} = \mathbf{392 \text{ W}}$ (3 significant figures).

Unit	Measures	Value in SI units
watt (W)	power	1 J/s
kilowatt (kW)	power	1000 W
horsepower (hp)	power	746 W
kilowatt-hour (kWh)	energy	$3.6 \times 10^6 \text{ J}$

Common mistake

Using the length of a slope instead of the vertical height in mgh . Gravitational potential energy depends only on vertical height. Another trap is calling the kilowatt-hour a unit of power: it is a unit of energy, equal to one kilowatt used for one hour.

Lina's tip

Draw the bar chart before you write any equation. If the bars of the final state do not add

up to the bars of the first state, you have forgotten a work term or some thermal energy.

Key points to remember

- Gravitational potential energy near Earth: $U_g = mgh$, with $g = 9.81 \text{ m/s}^2$
- Spring potential energy: $U_s = \frac{1}{2}kx^2$ (J)
- Energy account: $K_1 + U_1 + W_{\text{ext}} = K_2 + U_2 + \Delta E_{\text{int}}$
- Power: $P = \Delta E/t = W/t = Fv \cos\theta$, and $1 \text{ W} = 1 \text{ J/s}$
- $1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$, an energy unit and not a power unit

Energy conservation, bar charts and power: frequently asked questions

What is the difference between energy and power?

Energy is the amount stored or transferred, in joules. Power is how fast the transfer happens, in joules per second or watts. A small heater running all night can transfer more energy than a powerful oven running for a minute.

Why does the mass cancel in many conservation problems?

When only gravity acts, both the potential energy mgh and the kinetic energy $\frac{1}{2}mv^2$ are proportional to mass. Dividing both sides by m leaves $v = \sqrt{2gh}$, so a heavy and a light object released from the same height reach the same speed.

What does an energy bar chart show?

It shows how the energy of a system is shared between kinetic, potential and internal stores at a chosen moment. Comparing the charts for two moments shows whether energy was transferred in or out of the system.

Can gravitational potential energy be negative?

Yes. Its value depends on the reference level you choose, so an object below that level has negative U . Physical predictions use changes in U , which do not depend on the choice.

How do you convert kilowatt-hours to joules?

Multiply by 3.6×10^6 , because 1 kWh is 1000 W for 3600 s . For example, 0.25 kWh is $0.25 \times 3.6 \times 10^6 \text{ J} = 9.0 \times 10^5 \text{ J}$.