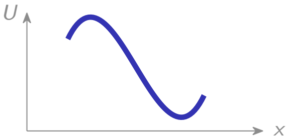
Work, Energy, and Power

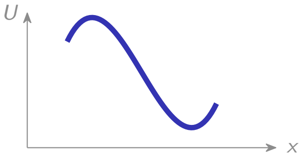
AP Physics C: Mechanics ▪ Unit 3

AP Physics C: Mechanics



What we will cover

1. Kinetic energy and the work-energy theorem
2. Work as an integral
3. Potential energy and force
4. Conservation of energy
5. Power



Kinetic energy and the work-energy theorem

Energy of motion

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

A **scalar** 标量; $\propto v^2$, so double the speed quadruples K.

Work-energy theorem

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

coaster Energy

Work as an integral

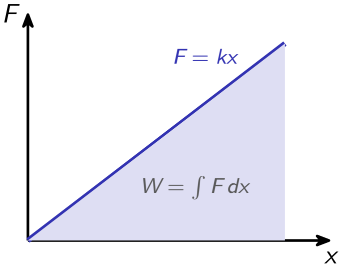
Constant vs variable force

$$W = \vec{F} \cdot \vec{d} = Fd\cos\theta$$

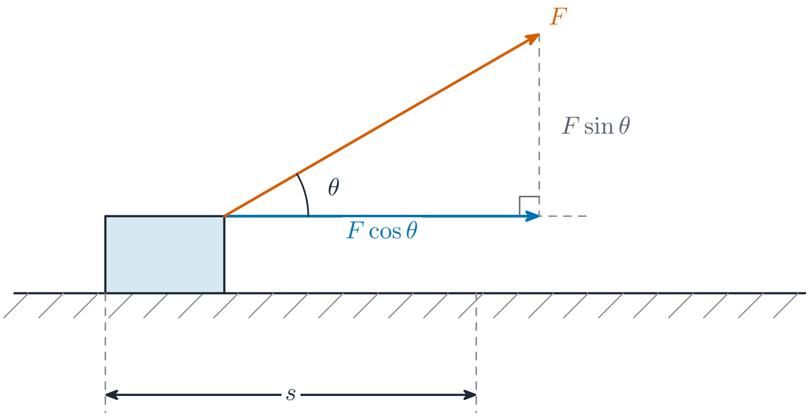
$$W = \int \vec{F} \cdot d\vec{r}$$

The integral is the area under an F–x graph.

Stretching a spring: $W = \int_0^x kx' \, dx' = \frac{1}{2}kx^2$.



Work as an integral



Potential energy and force

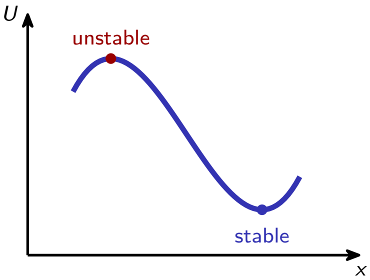
A **conservative force** 保守力 stores **potential energy** 势能:

Two stored forms, and the link

$$U_g = mgy, \qquad U_s = \tfrac{1}{2}kx^2$$

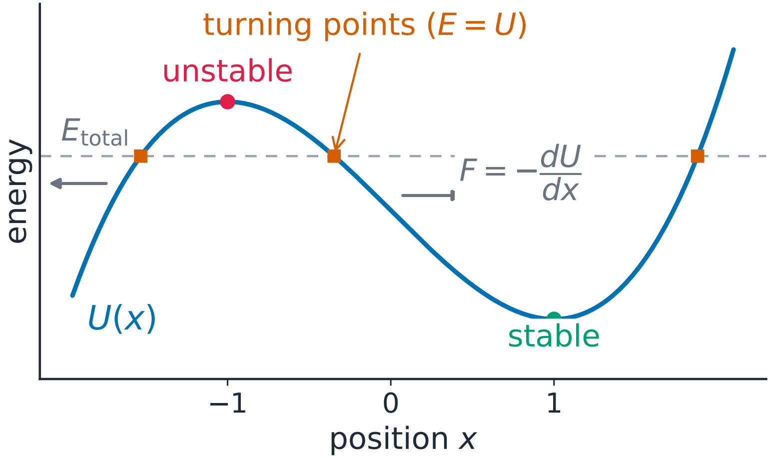
$$F_x = -\frac{dU}{dx}$$

For a spring $-\frac{d}{dx}(\frac{1}{2}kx^2) = -kx$ – Hooke's law drops out.



A valley is stable; a hilltop unstable.

Potential energy and force



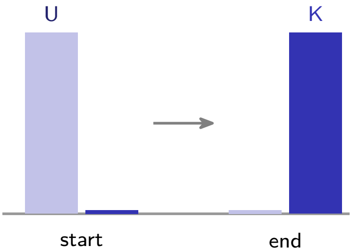
Conservation of energy

With only conservative forces, **mechanical energy is conserved** 机械能守恒:

Before = after

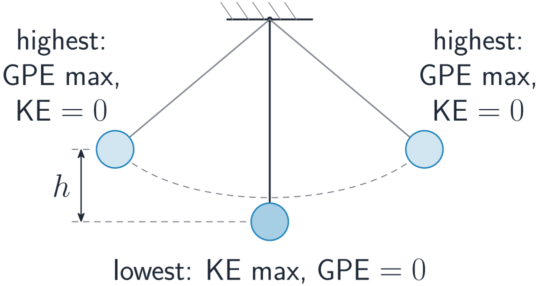
$$K_i + U_i = K_f + U_f$$

A **non-conservative force** 非保守力 like friction removes mechanical energy as heat.



Drop $1\,\mathrm{kg}$ from $5\,\mathrm{m}$: $v \approx 9.9\,\mathrm{m/s}$.

Conservation of energy



Power

Power 功率 is the rate of doing work:

Two forms

$$P = \frac{dW}{dt}, \qquad P = \vec{F} \cdot \vec{v}$$

Instantaneous power varies as force or speed changes.

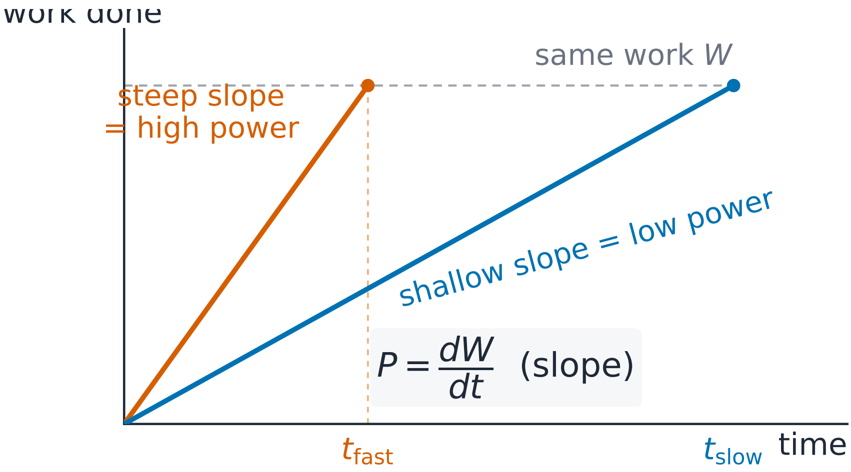
Worked example

Lift $50\,\mathrm{kg}$ at a steady $2\,\mathrm{m/s}$:

$$P = Fv = (490)(2) = 980\,\mathrm{W}$$

Twice as fast $\Rightarrow$ $1960\,\mathrm{W}$ – same work per metre, half the time.

Power


work done
same work W
steep slope
= high power
shallow slope = low power
$P = \frac{dW}{dt}$ (slope)
t_{fast}
t_{slow}
time

Unit 3 – key takeaways

1 **Work**

$W = \int \vec{F} \cdot d\vec{r}$; the area under an F–x graph

2 **Energy**

$K = \frac{1}{2}mv^2$; net work equals ΔK

3 **Potential**

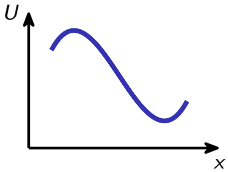
$F_x = -dU/dx$; valley stable, hill-top unstable

4 **Conservation**

$K + U$ constant; $P = dW/dt = \vec{F} \cdot \vec{v}$

Check yourself

1. What integral gives the work done by a variable force?
2. How do you get the force from a potential-energy function?
3. Is a potential-energy valley stable or unstable equilibrium?
4. Write instantaneous power as a dot product.



Answers **1.** $\int \vec{F}\cdot d\vec{r}$ **2.** $F_x = -dU/dx$ **3.** stable **4.** $P = \vec{F}\cdot\vec{v}$