Work, Energy, and Power Cheat Sheet

AP Physics 1 · Unit 3 · work, conservation of energy, power · g = 9.8 m/s²

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WORK BY A CONSTANT FORCE

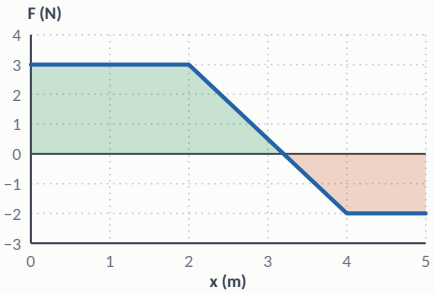
- $W = F_{\parallel} d = Fd \cos\theta$, where θ is the angle between the force and the displacement.
- 1 J = 1 N·m. Work is a scalar with a sign.
- W_{net} is the sum of the work done by each force.

Angle θ	Work
0° to less than 90°	positive
90°	zero
more than 90° to 180°	negative

WORK BY COMMON FORCES

Force	Work on the object
Gravity	$-mg\Delta y$, on any path
Normal force, fixed surface	0
Kinetic friction over sliding distance d	$-F_f d$, with $F_f = \mu_k F_N$
Rope or push at angle θ to the motion	$Fd \cos\theta$
Force toward the center of a circle	0
Any force on an object that does not move	0

WORK FROM A FORCE GRAPH



KEY

	$F_{\parallel}$ against x
	Area above the axis: positive work
	Area below the axis: negative work

Work = signed area between the $F_{\parallel}$ graph and the x-axis. Split it into rectangles and triangles. The force that stretches a spring by x is a line through the origin, so the work to stretch it is $\frac{1}{2}kx^2$.

WORK-ENERGY THEOREM

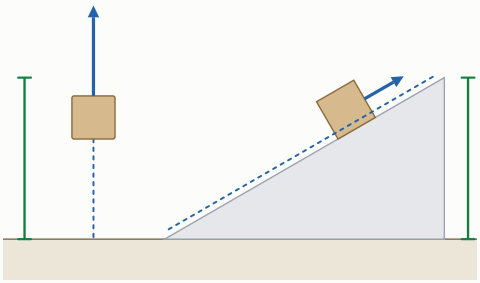
- $W_{net} = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
- For one object, with forces and distances given. Time does not appear.
- Skid to a stop on level ground: $d = v^2 / (2\mu_k g)$. Twice the speed, four times the distance.

Speed (m/s)	10	20	30
d when $\mu_k = 0.70$ (m)	7.29	29.2	65.6

CONSERVATION OF ENERGY

- When energy crosses the system boundary only through work: $\Delta K + \Delta U + \Delta E_{th} = W_{ext}$, where W_{ext} is work by forces from outside the system.
- $W_{ext} = 0$ and no friction inside: $K_i + U_i = K_f + U_f$.
- Kinetic friction: $\Delta E_{th} = F_f d$, with both surfaces in the system.
- Count gravity once: as W_g with the object alone, or as ΔU_g with the object and Earth.

INCLINES: RAMP VERSUS LIFT



KEY

	Crate of mass m, part way up
	Path of the crate
	Height gained, h (the same on both sides)
	Pull at constant speed: mg straight up, mg sin θ along a frictionless ramp (half as much at 30°)

At constant speed: $F = mg \sin\theta$ without friction, $F = mg(\sin\theta + \mu_k \cos\theta)$ with it, over a ramp length $L = h / \sin\theta$. Without friction $W_{pull} = mgh$ for any angle. Friction adds $\mu_k mg \cos\theta \cdot L$, which becomes thermal energy.

POWER

- $P_{avg} = W / \Delta t = \Delta E / \Delta t$
- $P = F_{\parallel} v = Fv \cos\theta$ at the instant the speed is v
- Lifting at constant speed: P = mgv

1 W	1 J/s
1 kW	1,000 W
1 kWh	3.6×10^6 J (energy, not power)
1 hp	about 746 W

FIVE CHECKS BEFORE YOU HAND IT IN

1. Is θ the angle between the force and the displacement?
2. Did I name the system and count gravity once?
3. Did I find F_N from the forces instead of assuming mg?
4. Is $\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$, not $\frac{1}{2}m(\Delta v)^2$?
5. Do the units fit: J or kWh for energy, W for power?