

Work done, power and mechanical energy

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Work is the energy transferred when a force moves an object, found from $W = F \times d$ and measured in joules. Power is how fast energy is transferred, $P = E \div t$, measured in watts. Kinetic energy is $KE = \frac{1}{2} m v^2$ and gravitational potential energy is $GPE = m g h$.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS3-1

What is work done in physics?

In physics, **work** is not tiredness. Work is done when a force moves an object, and the amount of work equals the energy transferred. Pushing a heavy cart a long way transfers a lot of energy. Pushing a wall that does not move transfers none.

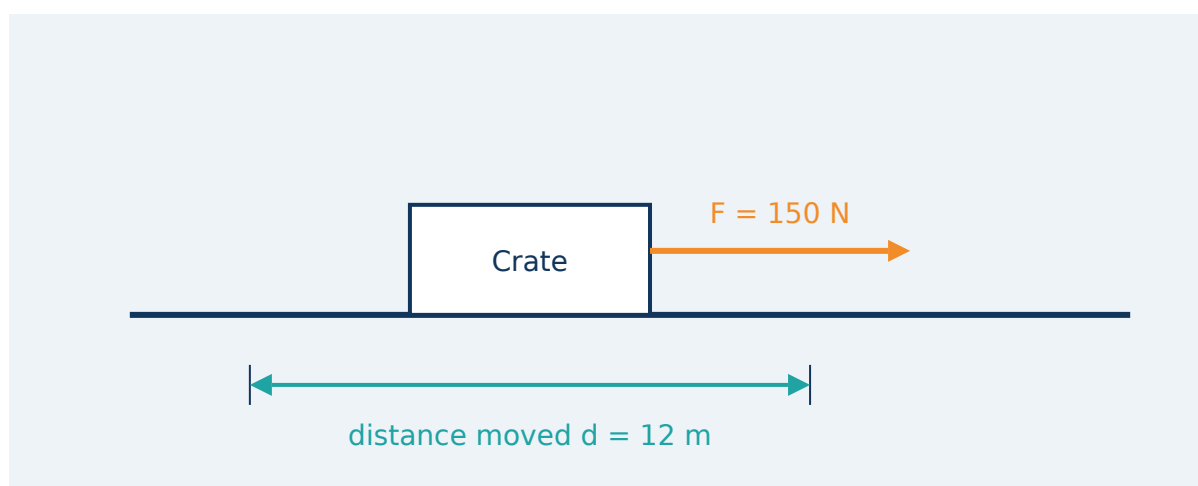
Definition

Work done is the energy transferred when a force moves an object through a distance in the direction of the force. It is measured in joules (J). One joule is the work done by a force of 1 N moving an object 1 m.

Formula

$$W = F \times d$$

W = work done in joules (J), F = force in newtons (N), d = distance moved in the direction of the force in metres (m).



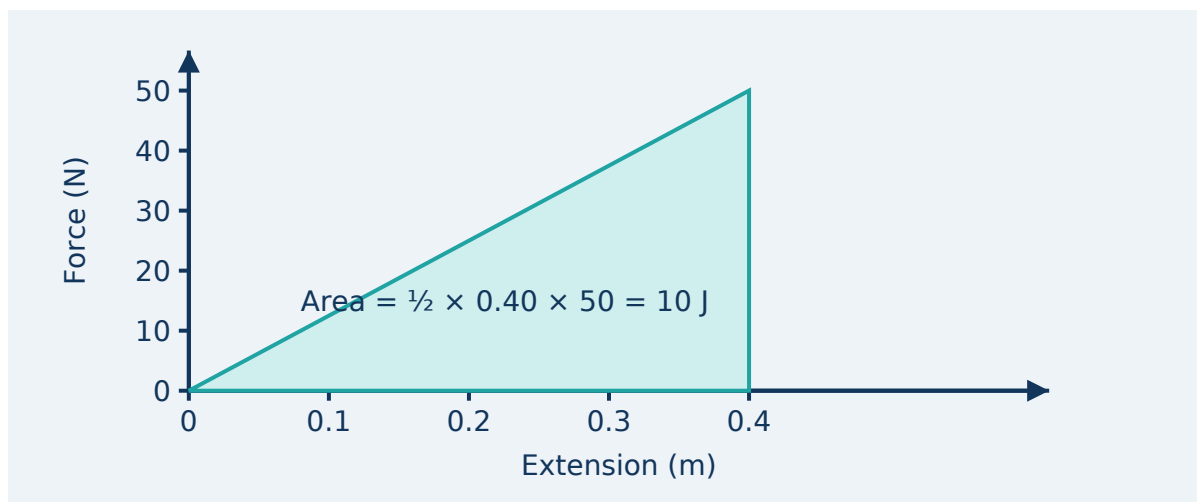
Work is done when a force moves an object through a distance in the direction of the force.

Worked example 1

Chiamaka in Lagos pulls a crate with a steady force of 150 N for 12 m along a level path.

$$W = F \times d = 150 \times 12 = \mathbf{1800 \text{ J.}}$$

If the force is not steady, plot a graph of force against distance. The work is the **area under the graph**, as the next figure shows for a stretched spring.



The area under a force-distance graph equals the work done.

How do you calculate power?

Two people can do the same work in different times. The one who is quicker has more power.

Definition

Power is the rate of doing work or transferring energy. Its unit is the watt (W): $1 \text{ W} = 1 \text{ J/s}$. A kilowatt is 1000 W.

Formula

$$P = W \div t = E \div t$$

P = power in watts (W), W or E = work done or energy transferred in joules (J), t = time in seconds (s).

Worked example 2

Aarav in Pune lifts a 20 kg sack of rice onto a shelf 1.5 m high in 3.0 s. Use $g = 9.8 \text{ N/kg}$.

Weight = $20 \times 9.8 = 196 \text{ N}$; $W = F \times d = 196 \times 1.5 = 294 \text{ J}$.

$P = W \div t = 294 \div 3.0 = \mathbf{98 \text{ W}}$.

Device or activity	Typical power
Phone charger	5 W
Walking up stairs (a student)	about 200 W
Kettle	2000 W (2 kW)
Car engine at cruising speed	about 20 000 W (20 kW)

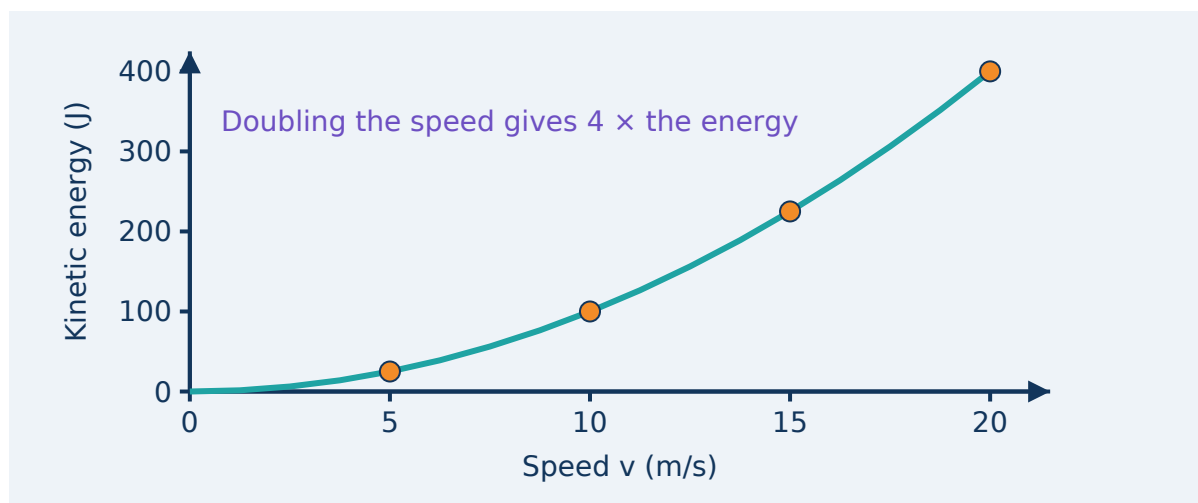
What are kinetic and gravitational potential energy?

Work changes the energy of an object. Two stores matter most in mechanics: the energy of motion and the energy of height.

Formulas

$$\text{KE} = \frac{1}{2} \times m \times v^2 \text{ and } \text{GPE} = m \times g \times h$$

KE = kinetic energy (J), m = mass (kg), v = speed (m/s), GPE = gravitational potential energy (J), g = 9.8 N/kg, h = height gained (m).



Kinetic energy of a 2.0 kg object: the curve rises as the square of the speed.

Worked example 3

A motorbike and rider have a mass of 150 kg and travel at 20 m/s.

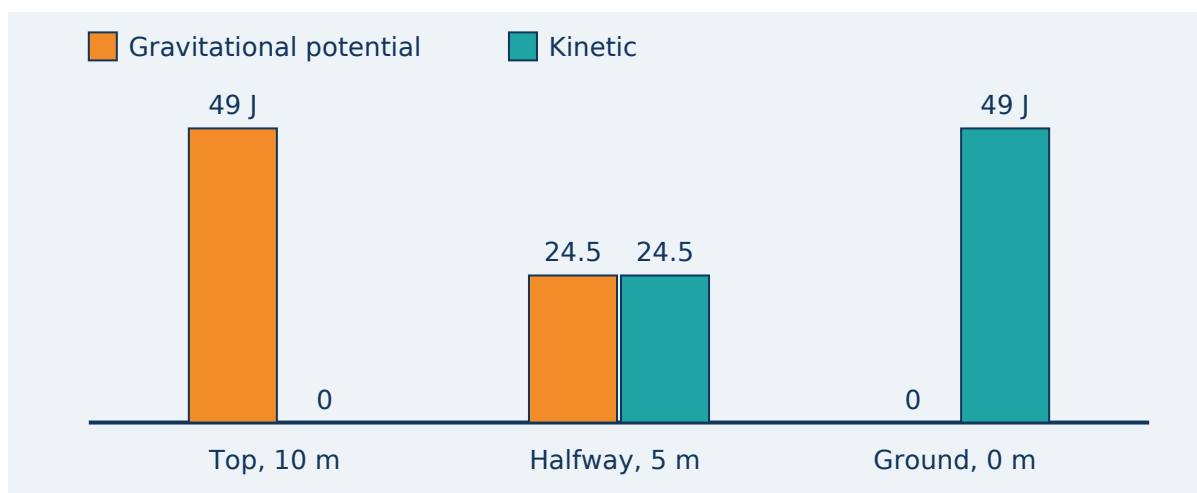
$$\text{KE} = \frac{1}{2} \times 150 \times 20^2 = \frac{1}{2} \times 150 \times 400 = \mathbf{30\,000\,J} \text{ (30 kJ)}.$$

Common mistake

Students double the speed and expect double the energy. Because v is squared, doubling the speed makes the kinetic energy **four times** bigger. Forgetting to square v, or squaring $\frac{1}{2} \times m$ too, are the other classic slips.

How are work and energy linked?

Work done on an object equals the energy transferred to it. A braking force does work against the motion, and that work removes the kinetic energy. When air resistance is small, a falling object converts potential energy into kinetic energy and the total stays constant.



As the ball falls, gravitational potential energy is converted to kinetic energy and the total stays 49 J.

Worked example 4

A car of mass 1000 kg moves at 15 m/s and stops with a constant braking force of 5000 N. $KE = \frac{1}{2} \times 1000 \times 15^2 = 112\,500 \text{ J}$. Work by brakes = $F \times d = KE$, so $d = 112\,500 \div 5000 = \mathbf{22.5 \text{ m}}$.

Lina's tip

Convert to SI units before you calculate: grams to kilograms, minutes to seconds, kilojoules to joules, and km/h to m/s by dividing by 3.6. Write the units next to every number.

Key points to remember

- Work: $W = F \times d$, in joules, with d in the direction of the force.
- Power: $P = W \div t = E \div t$; $1 \text{ W} = 1 \text{ J/s}$ and $1 \text{ kW} = 1000 \text{ W}$.
- Kinetic energy: $KE = \frac{1}{2} m v^2$; doubling the speed makes it 4 times larger.
- Gravitational potential energy: $GPE = m g h$, with $g = 9.8 \text{ N/kg}$.
- The area under a force-distance graph is the work done.

Work done, power and mechanical energy: frequently asked questions

What is the difference between work and power?

Work is the energy transferred by a force and is measured in joules. Power is how fast that work is done, measured in watts, so $P = W \div t$.

Why does carrying a bag along a level path do no work on the bag?

The upward force from your hands is at right angles to the horizontal motion. Work needs a force in the direction of movement, so the work on the bag by that force is zero.

Why is kinetic energy proportional to speed squared?

The work needed to speed something up depends on both the force and the distance, and both

grow with speed. This gives $KE = \frac{1}{2} m v^2$, so double the speed means four times the energy.

How many watts are in a kilowatt?

There are 1000 watts in one kilowatt. A 2 kW kettle transfers 2000 J every second.

Is the unit of work the same as the unit of energy?

Yes. Both are measured in joules, because work is a way of transferring energy. One joule equals one newton metre.