Work

The everyday definition of “work” and the one that we use in physics are quite different from each other.

- When most people think about “work” they think of the job that they have.
- In physics we use two very exact definitions of work.

**Definition 1:**

*Work is a transfer of energy*

**Definition 2:**

*Work is a force causing an object to have a displacement.*

Both of these definitions can be seen in the formula on your data sheet:

\[ W = \Delta E = Fd \]

- Notice that both of the definitions are shown in the formula.
- A **transfer of energy** means a change in energy \((\Delta E)\) is happening.
- It also shows that a **force and displacement** are happening.

Most of the time you don't even have to use the formula this way. You'll also see it on your data sheet as:

\[ W = F \cdot d \]

- \(W = \text{work (Joules)}\)
- \(F = \text{force (Newtons)}\)
- \(d = \text{displacement (metres)}\)

By definition, 1 J of work is done by applying 1 N of force to move an object 1 m.

- Work has no direction, so it is a **scalar** quantity.
- But, the direction of motion must be in the same direction (**parallel**) as the direction of the force, otherwise no work is being done.

**Example 1:** I am holding a 2 kg block of cheese in my hands. I walk 12 m to the other side of the room. **Explain** if I did any work.

Since I am holding the cheese **up** against gravity, the force I must be exerting on it will be pointing up. I moved **horizontally**, so the two vectors (force and displacement) are perpendicular to each other. I didn’t do any work.
Example 2: I decide to do a little weight lifting (but I’m going to start off slow!). I lift 10 kg from the floor, over my head, and back down to the floor. **Explain** if I did any work.

Well, in this case the force must be pointing up when I lift up the weights, and at first I’m moving them up, so it seems I am doing work. But wait… I said that I then bring the weights back down to the floor. Overall, the displacement of those weights is zero! Therefore I didn’t do any work.

Example 3: Last winter my car got caught in a snow bank. I promise one of my friends that if he comes over to do some work for me I’ll buy him a Whopper (with extra onions… he really likes onions). We get behind the car and push it out of the snow. **Explain** if we did any work.

In this situation, both of us were pushing in the same direction (parallel to each other) and the car moved in that direction. So the answer would be “Yes!” I do owe him a whopper for the work he did… but I’ll cut it in half and eat part of it myself since I did half the work.

Example 4: I am holding a 10kg book in my hand. I put it down on the floor. **Explain** if we did any work.

The force and displacement are parallel, but they do not point in the same direction. When I put the book down, I do NOT push the book down; instead, I push upwards with less force than gravity pulls down. My force is up, the displacement is down, so I didn't do any work. As a note, if you look at it in terms of gravity the Earth did work by pulling the book downwards.

Example 5: My daughter Katrien, grabs my son's Niels leg and drags him 2.3 m across the floor. If she exerted a force of 8.1 N to do this, **determine** how much work she did.

\[
W = F \cdot d = 8.1 \text{ N} \cdot (2.3 \text{ m}) = 19 \text{ J}
\]

When you look at the answer you just calculated, you’ll also want to keep in mind the first definition of work.

- Since work is a transfer of energy it applies to the example above. Katrien is transferring chemical energy stored in her body into kinetic energy of Niels going across the floor.
- This definition is also useful if you know something about how energy is changing forms.

We sometimes call the total energy of an object (potential and kinetic) the **mechanical energy** of an object.

- This would mean that doing work on an object in some way changes the mechanical energy of the object.
- “Mechanical” energy doesn’t mean that it always has to involve machines.
  - In fact, most of the time it has nothing to do with a machine.
  - An apple falling off a cliff has potential and kinetic energy, so it therefore has mechanical energy.
- We will look at mechanical energy in detail later.
It is possible for work to be done when the vectors of force and displacement are not exactly parallel. 

- The only time that absolutely no work is done is when they are **exactly** perpendicular to each other.
- You’ll need to calculate the component of the force vector that is parallel to the displacement.
- Look at the situation of a person pulling a box on the end of a rope that makes a 30° angle to the ground…

![Diagram of a person pulling a box](image)

- The box moves to the right, and the force is pointing diagonally up. To figure out the x-component of the force, we need to draw a right angle triangle.
- To figure out $F_x$, we would use cosine, since we have the hypotenuse and we are trying to calculate the side adjacent to the angle.

$$\cos \theta = \frac{adj}{hyp} = \frac{F_x}{F}$$

$$F_x = F \cos \theta$$

So if you need to calculate the work done by a force to displace an object, but the vectors are not parallel (but not perpendicular either!), you could use the formula…

$$W = F \cdot d \cos \theta$$

$\theta$ = the angle between the Force and Displacement vectors.

**Example 6:** If you were pulling a box like in the example above, which moves 12.7 m when you pull along the rope with a force of 76.0 N, **determine** how much work you did.

$$W = F \cdot d \cos \theta$$

$$= 76.0 \text{ N} \times (12.7 \text{ m}) \times \cos 30.0^\circ$$

$$W = 836 \text{ J}$$