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 (ΔE) 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:

$$W = F\,d$$

W = work (Joules)
F = force (Newtons)
d = 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.

> $W = F\,d = 8.1\text{ N }(2.3\text{ m}) = 19\text{ J}$

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

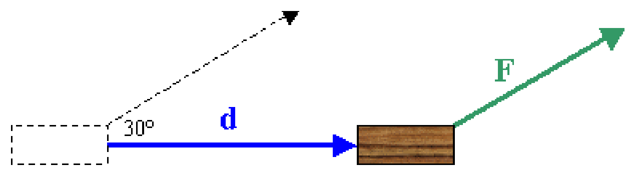
- Since work is a transfer of energy it applies to the example above. Katrien is transferring chemical energy stored in her body into kinetic energy of Niels going across the floor.
- This definition is also useful if you know something about how energy is changing forms.

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

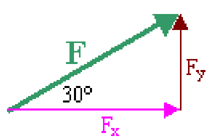
- This would mean that doing work on an object in some way changes the mechanical energy of the object.
- "Mechanical" energy doesn't mean that it always has to involve machines.
  - In fact, most of the time it has nothing to do with a machine.
  - An apple falling off a cliff has potential and kinetic 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…



- 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 the side adjacent to the angle.



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

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…

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

θ = 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.

$$W = F\, d \cos\theta$$
$$= 76.0\text{ N }(12.7\text{ m}) \cos 30.0°$$
$$W = 836\text{ J}$$