Work

by

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P4.1c Explain why work has a more precise scientific meaning than the meaning of work in everyday language.

P4.1d Calculate the amount of work done on an object that is moved from one position to another.

Items:

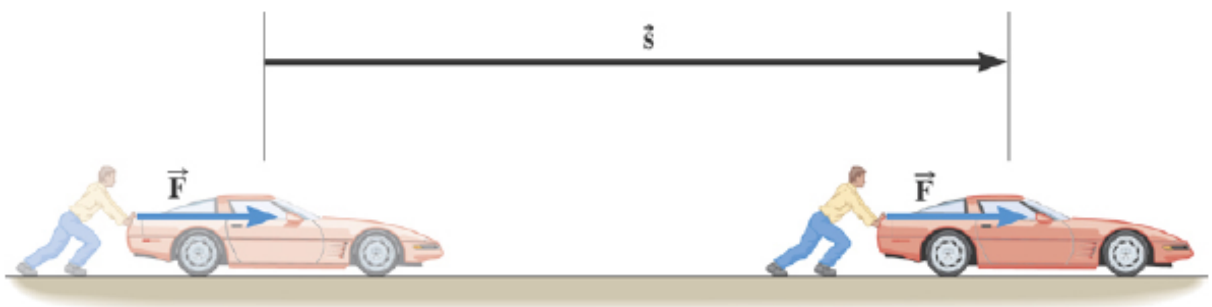
1. Work.

2. Power.

3. Work and Energy .

Work

Work (W) is done on an object whenever a force makes that object move- When a car's engine makes the car accelerate, when a crane lifts a steel beam for a new building. A boy pushing a car in the picture below is an example of work.



If you exert efforts on an object and the object does not move, then you are not doing work. Even though you may perspire when holding a heavy object on your shoulder, you are not doing any work on that object because you are not moving it.

The amount of work done is calculated by multiplying the force (F) that was applied by the displacement (S) of the object. The unit of force is Newton (N) and the unit of displacement is meter (m). The unit of work is Joule (J).

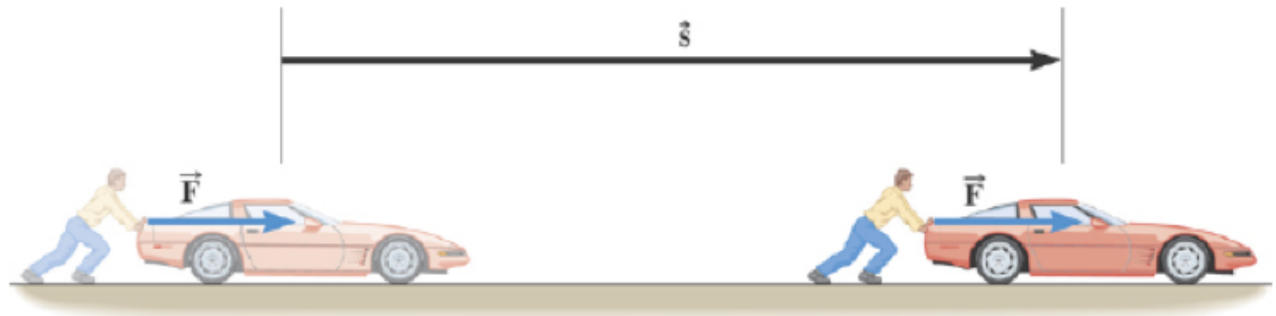
Work	
$W_{(J)} = F_{(N)} \times S_{(m)}$	**Derivatives of the equation:** $F_{(N)} = W_{(J)} / S_{(m)}$ $S_{(m)} = W_{(J)} / F_{(N)}$

The two units frequently used to measure work are joules and kilowatt hours (kw.h).

$$1 \text{ kw.h} = 3.6 \times 10^6 \text{ J}$$

Example 1: Pushing a Car.

How much work is done by a boy pushing a car with a force of 800 N (F = 800 N) for a distance of 2 m (S = 2 m)?



Data Table		
F	*S*	*W*
800 N	2 m	?

$$W_{(J)} = F_{(N)} \times S_{(m)}$$

$$= (800\ N)\ (2\ m) = 1600\ joules.$$

The boy does 1600 joules of work.

Example 2: *Using a Pail to Get Water from a Well.*

A camper uses a rope and pail to get water from a well. If the pail with water has a mass of 20 kg and if it is raided a vertical distance of 3.5 m, how much work is done by the camper?

(F_g = m x g)

To move the pail straight up at a constant speed, you only need to lift with a force that is slightly larger than the force of gravity (F_g) directed toward the center of the Earth (blue arrow). We will assume that the force needed is equal to the force of gravity on the object and that it is constant for the whole interval.

Data Table				
m	g	s	F_g	W
20 kg	9.8 N/kg	3.5 m	?	?

$$F_g = m \times g = 20 \times 9.8 = 200 \text{ N.}$$

$$W = F \times S = 200 \times 3.5 = 700 \text{ Joules}$$

The camper does 700 Joule of work in lifting the pail of water from the well.

Power

Power (P) is defined as the rate at which work is done.

It is determined by dividing the work (W) done by the time (Δt) required.

If the work is in joules (j) and the time in seconds (s), the power will be in watts (w).

Power Equation	
$P_{(w)} = W_{(j)} / \Delta t_{\ (s)}$	**Derivatives of the equation:** $W_{(j)} = P_{(w)} \times \Delta t_{\ (s)}$ $\Delta t_{\ (s)} = W_{(j)} / P_{(w)}$

Example 3: *Power of a Bulldozer.*

What is the power of a bulldozer that does 5.5×10^4 J of work in 1.1s?

Data Table		
W	Δt *or time*	P
5.5×10^4 J	1.1 s	?

$$P = w / \Delta t$$

$$= 5.5 \times 10^4 / 1.1$$

$$= 5.0 \times 10^4 \text{ W or Watts.}$$

Example 4: Running Up the Stairs.

How much power is developed by a 60 kg boy running up a 4.5 m high flight of stairs in 4.0 s?

Data Table					
m	g	s	F_g	W	P
60 kg	9.8 N/kg	4.5 m	?	?	?

The gravitational force (F_g) on the boy:

$$F_g = m \times g = 60 \times 9.8 = 588 \text{ N.}$$

The work done by the boy:

$$W = F \times S = 500 \times 4.5 = 2646 \text{ Joules}$$

The power developed by the boy:

$$P = w / \Delta t$$

$$= 2646 / 4.0$$

$$= 660 \text{ w}$$

The boy develops 660 watts of power.

Energy

No machine can operate without fuel. Food is the fuel for the human body. Food gives you the ability to do work. It gives you energy.

Energy (E) is the ability to do work. Work (W) is the transfer of energy.

Both work and energy have the same unit, the joule (J) . So if you do 5000 J of work on an object, you have transferred 5000 J of your energy to it. Doing work on an object increases its energy.

$$W = \Delta E$$

W is the work done on an object, in joules

ΔE is the change in energy of the objects, in joules.

Friction does a negative work on an object because it removes energy from it.

Example 5: A Plastic Bin Pushed Along the Floor.

A clerk gives a plastic bin of groceries a push along the floor. An average frictional force of 52 N causes the bin to come to rest after sliding 1.9 m. How much work is done by the force of friction?

The direction of the frictional force is opposite to the displacement. It is given a negative value.

Data Table		
F	*S*	*W*
-52 N	1.9 m	?

$$W_{(J)} = F_{(N)} \times S_{(m)}$$

$$= (-52\text{ N})\ (1.9\text{ m}) = -99\text{ joules.}$$

The work done on the bin by the floor is -99 J. This means that 99 J of energy is transferred from the bin.

Example 6: *Work and Energy; Another Scientific Definition of Work;*

Work is the amount of energy transferred during an interaction. In mechanical systems, work is the amount of energy transferred as an object is moved through a distance, $W = F\ d$, where d is in the same direction as F. The total work done on an object depends on the net force acting on the object and the object's displacement.

Practice Problems:

Work:

1) A force of 20 N was used to push a box 8.0 m along the floor. How much work was done?

   Answer: 1.6×10^2 J

2) A 2,0 kg puck accelerated at 5.0 m/s^2 for 0.50 m across a frictionless air hockey table. How much for was one on the puck?

   Answer: 5.0 J

3) A bulldozer pushed a large rock with a force of 5000 N at 2.0 m/s for 20 s. How much work was done by the bulldozer?

   Answer: 2.0×10^5 J

Power:

1) How much power does a crane develop doing 6.0×10^4 J of work in 5.00 min?

Answer: 2.0×10^2 W

2) How long does it take a 2500 W electric motor to do 7.5×10^4 J of work?

Answer: 30 s

3) How much power is developed by a 50 kg girl running up a 3.00 m high flight of stairs in 2.5 0 s?

Answer: 5.9×10^2 W

References:

1) Humanic. (2013). www.physics.ohio-state.edu/~humanic/. In Thomas Humanic Brochure Page.

Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current. www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

4) Zitzewitz, P. W. (1999). *Glencoe Physics Principles and Problems*. New York: McGraw-Hill Companies, Inc.

5) Schnick, W.J. (n.d.). *Calculus-based physics, A Free Physics Textbook*. Retrieved from http://www.anselm.edu/internet/physics/cbphysics/index.html

6) Nada H. Saab (Saab-Ismail), (2010-2013) Westwood Cyber High School, Physics.

7) Nada H. Saab (Saab-Ismail), (2009- 2014) Wayne RESA, Bilingual Department.