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Work and Kinetic Energy

Module Overview

Acknowledgments

This presentation is based on and includes content derived from the following OER resource:

University Physics Volume 1

An OpenStax book used for this course may be downloaded for free at:
https://openstax.org/details/books/university-physics-volume-1

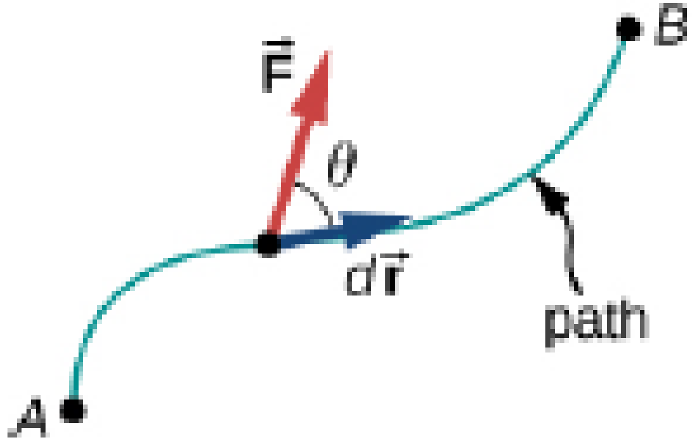
Work, Part 1

Work is the energy used when a force acts on an object to move it through some displacement. The work done by a force over an infinitesimal displacement, $d\vec{\mathbf{r}}$, is given by $dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = \left|\vec{\mathbf{F}}\right| |d\vec{\mathbf{r}}| \cos\theta$.

The SI unit of work is the joule, J, which is equal to the energy expended by a newton force over one meter, $1\ \mathrm{N} \cdot \mathrm{m} = 1\ \mathrm{J}$.

Work, Part 2

The total work done over a path from point A to point B is the integral of the infinitesimal expression for work, $W_{AB} = \int_{\text{path } AB} \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$. Note that this expression depends on the path taken between the two points. In particular, work is equal to zero if the force is perpendicular to the displacement.



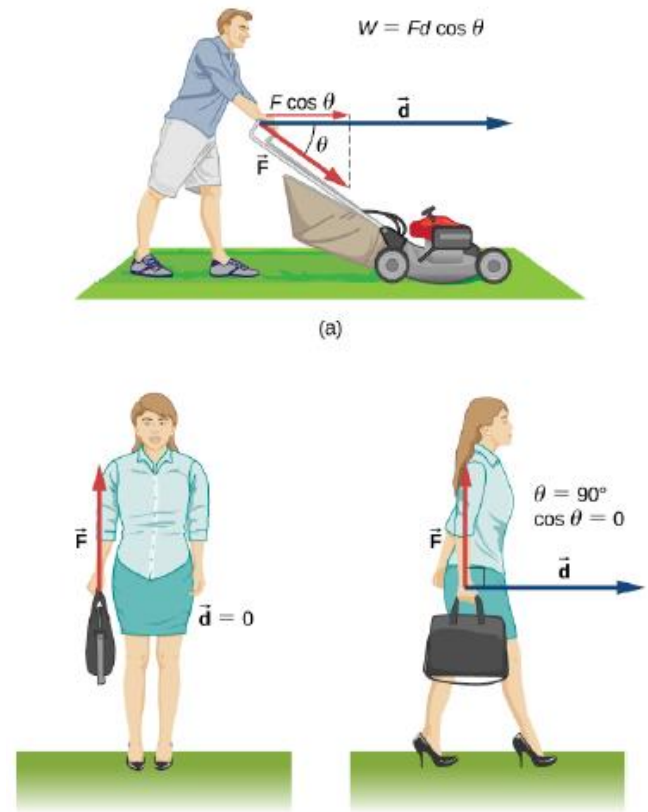
(University Physics Volume 1. OpenStax. Fig. 7.2)

Work Done by Constant and Contact Forces, Part 1

When the force on an object is constant, it can be pulled out of the integral,

$$W_{AB} = \vec{\mathbf{F}} \cdot \int_A^B d\vec{\mathbf{r}} = |\vec{\mathbf{F}}||\vec{\mathbf{r}}_B - \vec{\mathbf{r}}_A| \cos\theta.$$

In this case, the work done is not dependent on the path, but only on its beginning and end points.

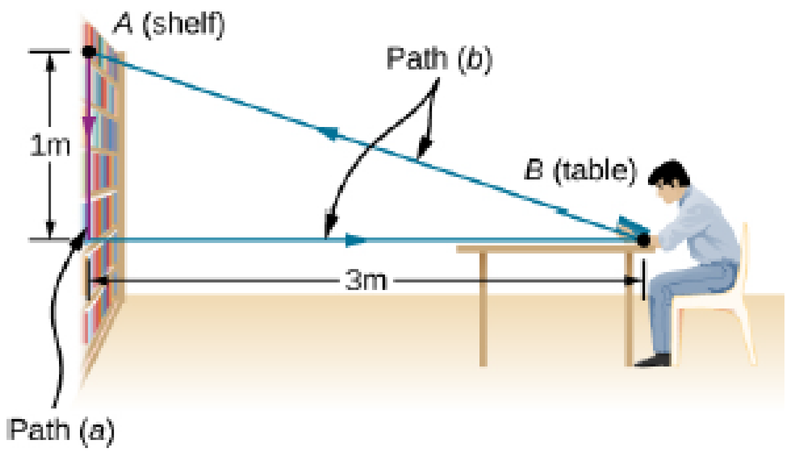


(University Physics Volume 1. OpenStax. Fig. 7.3)

Work Done by Constant and Contact Forces, Part 2

The friction force removes energy from an object by applying force opposite the direction of motion, $W_{\mathrm{fr}} = -f_k|l_{AB}|$, where $|l_{AB}|$ is the path length.

The gravitational force does work by applying a downward force as an object falls, $W_{\mathrm{grav},\ AB} = -mg(y_B - y_A)$.



(University Physics Volume 1. OpenStax. Fig. 7.5)

Work Done by Varying Forces

Forces that vary can be integrated over space to find the work done. The work done by Hooke's law is given by integrating the force over displacement. Note that the work done depends only on the end points.

$$W_{\text{spring},\,AB} = -k\int_A^B x\,dx = -\frac{1}{2}k\left(x_B^2 - x_A^2\right)$$

Kinetic Energy

Kinetic energy is the energy of motion. For a particle of mass m moving at velocity v, the kinetic energy is defined as $K = \frac{1}{2}mv^2$. In terms of momentum, it can be written as $K = \frac{p^2}{2m}$. For a system of particles, the kinetic energy is the sum of that for each of the particles, $K = \sum \frac{1}{2}mv^2$.

Kinetic energy depends on frame of reference because of its dependence on velocity. It is often useful to divide total kinetic energy of a system into parts due to translational, rotational, and vibrational motions.

The Work-Energy Theorem

The **work-energy theorem** relates the work done on a particle with the change in its kinetic energy: $W_{\text{net}} = K_B - K_A$.

This important result can dramatically simplify the analysis of otherwise complicated problems that cannot easily be solved with Newton's laws.

(University Physics Volume 1. OpenStax. Fig. 7.11)

Power

Power is the rate at which work is done on a system. **Average power** is given by the work done over the change in time, $P = \frac{\Delta W}{\Delta t}$. Instantaneous power is defined as the time derivative of work, $P = \frac{dW}{dt}$.

Power can also be expressed in terms of the forces acting on a body.

$$P = \frac{dW}{dt} = \frac{\vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}}{dt} = \vec{\mathbf{F}} \cdot \frac{d\vec{\mathbf{r}}}{dt} = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$$

How to Study this Module

- Read the syllabus or schedule of assignments regularly.
- Understand key terms; look up and define all unfamiliar words and terms.
- Take notes on your readings, assigned media, and lectures.
- As appropriate, work all questions and/or problems assigned and as many additional questions and/or problems as possible.
- Discuss topics with classmates.
- Frequently review your notes. Make flow charts and outlines from your notes to help you study for assessments.
- Complete all course assessments.