Energy and energy transfer

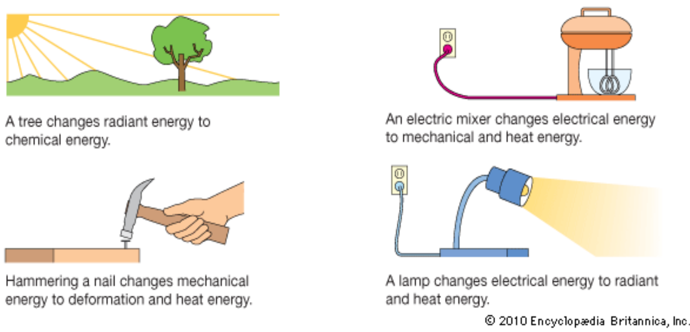
Energy and energy transfer

Chapter Outline:

- *The scalar product of two vectors.*
- *Work done by a constant force.*
- *Kinetic energy.*
- *The Work-Kinetic Energy Theorem.*
- *Power.*

Energy and energy transfer

Forms of energy:
* Mechanical (focus for now)
*Chemical
* Electromagnetic
* Nuclear
Energy can be transformed from one form to another

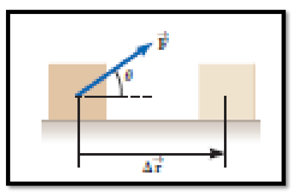


Work Done by a Constant Force:

Work *W* is energy transferred to or from an object by means of a force acting on the object.

- **Energy transferred to the object is positive work,**
- **Energy transferred from the object is negative work.**

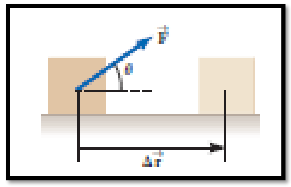
 # A force that results in no displacement does no work
 # A displacement that results with no applied force has had no work done (orbital motion, for example)



Work Done by a Constant Force:

The **work** W done on a system by an agent exerting a constant force on the system is the product of the magnitude F of the force, the magnitude Δr of the displacement of the point of application of the force, and $\cos\theta$, where θ is the angle between the force and displacement vectors:

$$W = \vec{F} \cdot \Delta\vec{r} = F\Delta r cos\theta$$

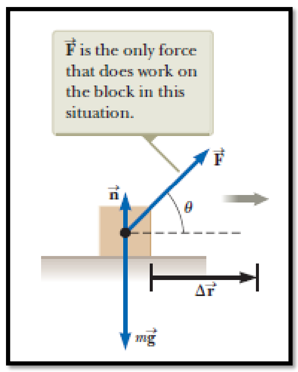


Work Done by a Constant Force:

The units of work are those of force multiplied by those of length. Therefore, the SI unit of work is the **newton·meter**

$$(\text{J} = N \cdot m = kg \cdot m^2/s^2)$$

This combination of units is used so frequently that it has been given a name of its own, the **joule** (J).



Work Done by a Constant Force:

Force (N)

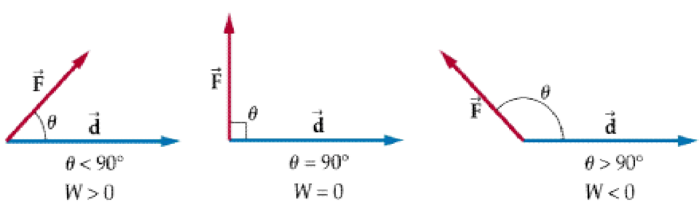
Work (joules) → $W = Fd\cos(\theta)$ ← Angle

Distance (m)

- **Work is a scalar quantity!!!! (Not a vector)**

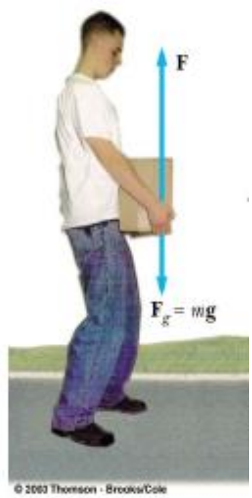
Work Done by a Constant Force:

- **Work can be positive or negative**
- **Positive if the force and the displacement are in the same direction.**
- **Negative if the force and the displacement are in the opposite direction.**



Work Done by a Constant Force:

- Man does positive work lifting box
- Man does negative work lowering box
- Gravity does positive work when box lowers
- Gravity does negative work when box is raised



Work (joules) → $W = mgh$

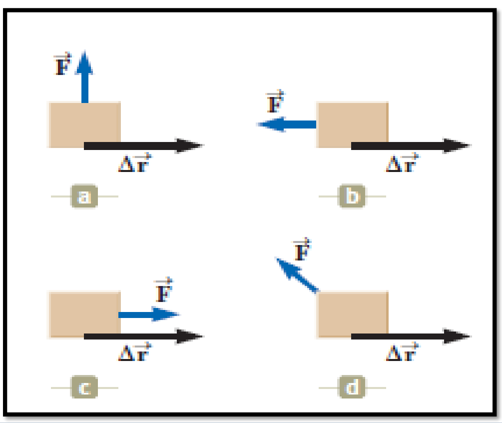
Mass (g)

Height object raised (m)

Gravity (m/sec²)

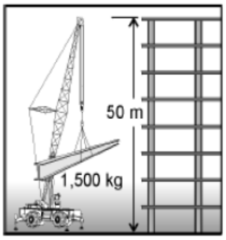
Work Done by a Constant Force:

Quiz: A force is applied to an object. In all four cases, the force has the same magnitude, and the displacement of the object is to the right and of the same magnitude.
Rank the work done by the force on the object, from most positive to most negative.

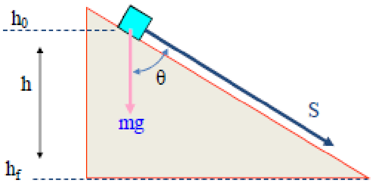


Example

- **A crane lifts a steel beam with a mass of 1,500 kg. Calculate how much work is done against gravity if the beam is lifted 50 meters in the air.**



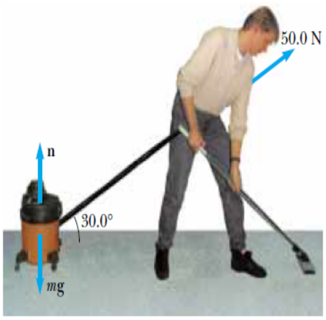
Example 2: Slide block down incline



Example

Example 7.1 Mr. Clean

A man cleaning a floor pulls a vacuum cleaner with a force of magnitude $F = 50.0$ N at an angle of 30.0° with the horizontal (Fig. 7.5a). Calculate the work done by the force on the vacuum cleaner as the vacuum cleaner is displaced 3.00 m to the right.



The Scalar Product of Two Vectors

Example 7.2 The Scalar Product

The vectors **A** and **B** are given by $\mathbf{A} = 2\hat{\mathbf{i}} + 3\hat{\mathbf{j}}$ and $\mathbf{B} = -\hat{\mathbf{i}} + 2\hat{\mathbf{j}}$.

(A) Determine the scalar product $\mathbf{A} \cdot \mathbf{B}$.

(B) Find the angle θ between **A** and **B**.

Example

Example 7.3 Work Done by a Constant Force

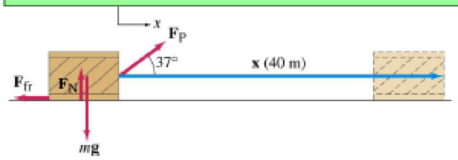
A particle moving in the *xy* plane undergoes a displacement $\Delta\mathbf{r} = (2.0\hat{\mathbf{i}} + 3.0\hat{\mathbf{j}})$ m as a constant force $\mathbf{F} = (5.0\hat{\mathbf{i}} + 2.0\hat{\mathbf{j}})$ N acts on the particle.

(A) Calculate the magnitudes of the displacement and the force.

(B) Calculate the work done by **F**.

Example

A 50.0-kg crate is pulled 40.0 m by a constant force exerted (F_P = 100 N and θ = 37.0°) by a person. A friction force F_f = 50.0 N is exerted to the crate. Determine the work done by each force acting on the crate.



Work and Energy

Example

The weight lifter is bench-pressing a barbell whose weight is 710N. In part (b) of the figure, he raises the barbell a distance of 0.65m above his chest, and in part (c) he lowers it the same distance.
The weight is raised and lowered at a constant velocity. Determine the work done on the barbell by the weight lifter during (a) lifting phase and (b) the lowering phase.

Work Done by a Varying Force

Using Newton's second law, we substitute for the magnitude of the net force $\sum F = ma$ and then perform the following chain-rule manipulations on the integrand:

$$\sum W = \int_{x_i}^{x_f} ma\,dx = \int_{x_i}^{x_f} m\frac{dv}{dt}dx = \int_{x_i}^{x_f} m\frac{dv}{dx}\frac{dx}{dt}dx$$

$$= \int_{v_i}^{v_f} mv\,dv$$

$$\sum W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

where v_i is the speed of the block at $x = x_i$ and v_f is its speed at x_f.

7.5 Kinetic Energy and the Work–Kinetic Energy Theorem:

the kinetic energy K of a particle of mass m moving with a speed v is defined as:

$$K \equiv \frac{1}{2}mv^2$$

- Kinetic energy is a scalar quantity
- Kinetic energy has the same units as work.
- K is always positive .

$$\sum W = K_f - K_i = \Delta K \qquad (2)$$

Equation (2) is an important result known as the **work–kinetic energy theorem:** When work is done on a system and the only change in the system is in its speed, the net work done on the system equals the change in kinetic energy of the system.

7.5 Kinetic Energy and the Work–Kinetic Energy Theorem:

- The speed of a system *increases* if the net work done on it is *positive* because the final kinetic energy is greater than the initial kinetic energy.
- The speed *decreases* if the net work is *negative* because the final kinetic energy is less than the initial kinetic energy.

7.5 Kinetic Energy and the Work–Kinetic Energy Theorem:

Example 7.7 A Block Pulled on a Frictionless Surface

A 6.0-kg block initially at rest is pulled to the right along a horizontal, frictionless surface by a constant horizontal force of 12 N. Find the speed of the block after it has moved 3.0 m.