Physics A - PHY 2048C

Work and Energy

10/30/2019

My Office Hours:
Thursday 2:00 - 3:00 PM

212 Keen Building

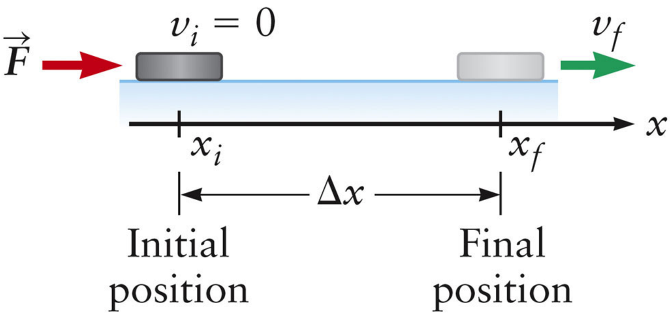
Warm-up Questions

1. Did you read the chapter on Work in the textbook?
2. What is the work done by static friction?
3. What is the work done by a centripetal force?

Applied Forces

Experiments have verified that the product of the force and the distance remains the same:

➜ To accelerate an object to a specific velocity, you can exert a large force over a short distance or a small force over a long distance.



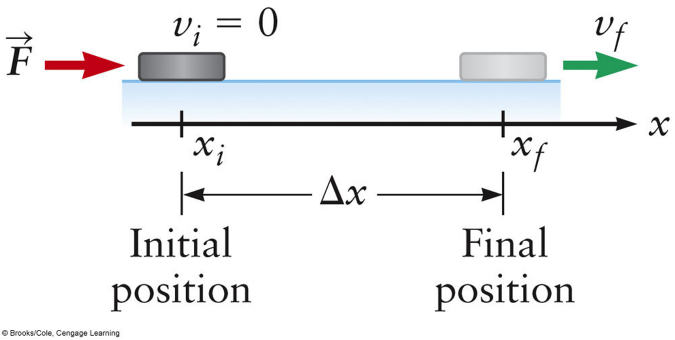
Outline

Work

Experiments have verified that the product of the force and the distance remains the same:

➜ Product of $F\Delta x$ is called work. In 1-dimensional motion:

$$W = F\Delta x$$



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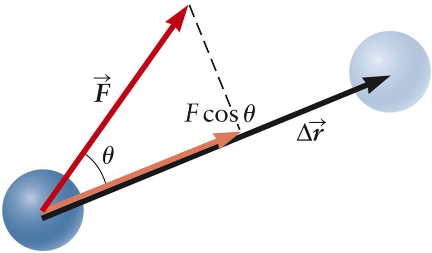

Work

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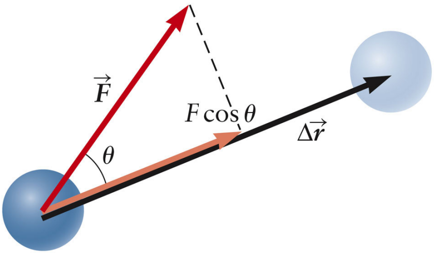
➜ Product of $F\Delta x$ is called work. In 2-dimensional motion:

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

where θ is the angle between force and displacement.



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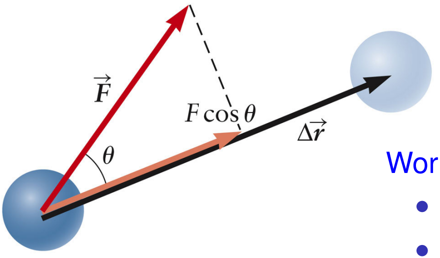


Work is a scalar:

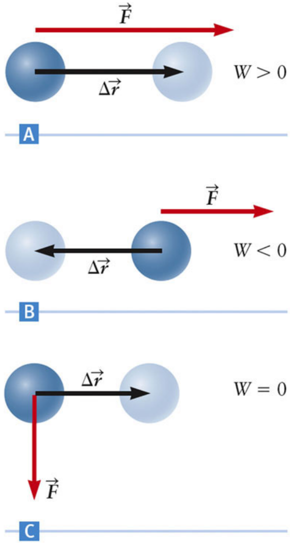
- Unit: N $\times$ m = Joule (or J)
- Can be positive or negative

Work and Directions

When the component of the force is parallel to the displacement, the work is positive.

When the component of the force is antiparallel to the displacement, the work is negative.

When the component of the force is perpendicular to the displacement, the work is zero.

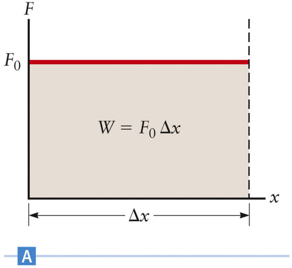


Graphical Analysis of Work

If the displacement is zero (the object does not move), then $W = 0$, even though the force may be very large.

Assume the force is constant:

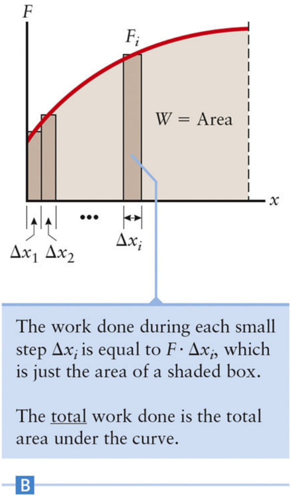
- When the force is constant, the graph is a straight line.
- The work is equal to the area under the plot.



Graphical Analysis of Work

Force doesn't have to be constant:

- For each small displacement, Δx, you can calculate the work and then add those results to find the total work.
- The work is still equal to the area under the curve.



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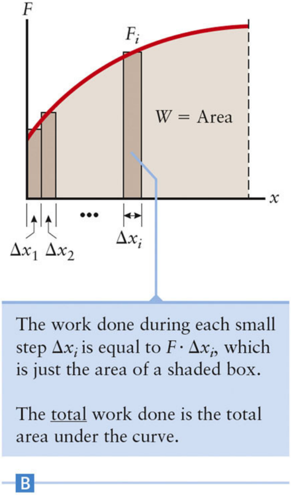
What happens to all the work?



Outline

Kinetic Energy

The force in the work equation can be found from Newton's Second Law:

$$W = F\,\Delta x = m\,a\,\Delta x$$

Acceleration can be expressed in terms of velocities:

(Remember: $v_f^2 = v_i^2 + 2a\,\Delta x$)

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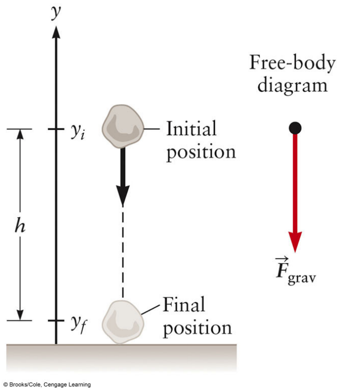
$$W = \frac{1}{2}\,m\,v_f^2 - \frac{1}{2}\,m\,v_i^2$$

Term $\frac{1}{2}mv^2$ is *kinetic energy.*



Kinetic Energy

The kinetic energy of an object can be changed by doing work on the object. This is called the *Work-Energy theorem:*

$$W = \Delta KE$$

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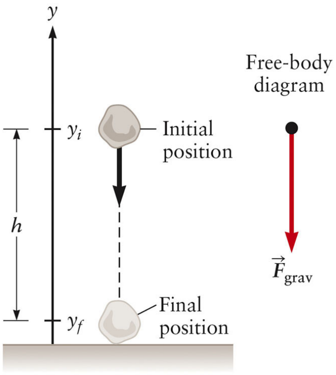


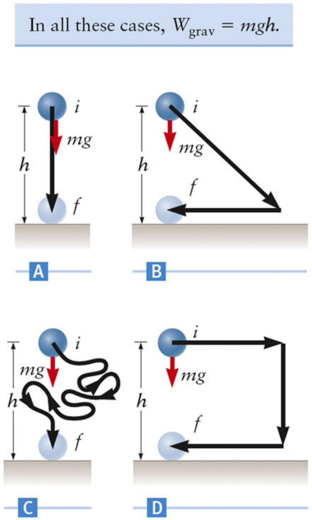
Potential Energy

When an object of mass m follows any path moving through a vertical distance h, the work done by the gravitational force is always equal to:

$$W = F\,\Delta x$$
$$= mg\,h$$

An object near the Earth's surface has *potential energy* (PE) depending only on the object's height, h.

The work done by the gravitational force as object moves from its initial position to its final position is indeed independent of the path taken.



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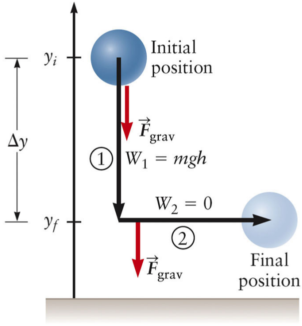


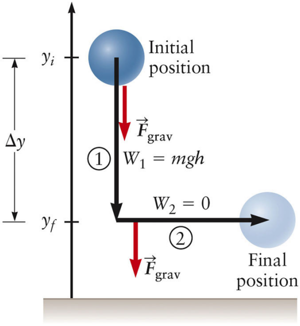
Potential Energy

Relation between work and potential energy:

$$\Delta PE = PE_f - PE_i = -W$$

Potential energy is stored energy:

- Energy can be recovered by letting object fall back down to its initial height, gaining kinetic energy.



Mechanical Energy

The sum of the potential and kinetic energies in a system is called the mechanical energy.

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Conservation of Mechanical Energy:

$$KE_i + PE_i = KE_f + PE_f$$

This is true as long as all forces are *conservative forces.* These are forces that are associated with a potential energy function. They can be used to store energy as potential energy.

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Examples of non-conservative forces: air drag and friction.

Power

Time enters into the ideas of work and energy through the concept of power.

The average power is defined as the rate at which the work is being done:

$$P_{\mathrm{ave}} = \frac{W}{t} = \frac{F\,\Delta x}{t} = F\,v_{\mathrm{ave}}$$

Units of power are watts: 1 W = 1 J/s.

For a given power:

- The motor can exert a large force while moving slowly.
- The motor can exert a small force while moving quickly.