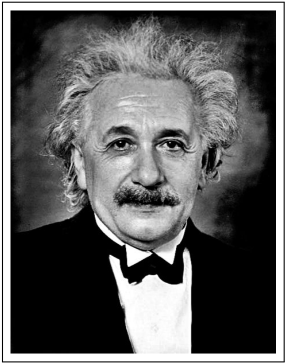
Chatper 7 - Kinetic Energy and Work



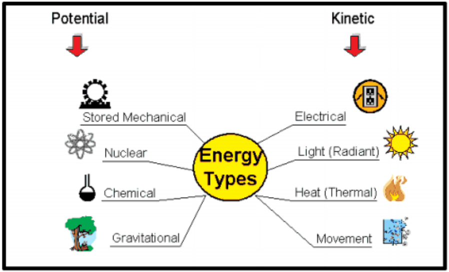
"The release of atomic energy has not created a new problem. It has merely made more urgent the necessity of solving an existing one."

- *Albert Einstein*

David J. Starling
Penn State Hazleton
PHYS 211

Kinetic Energy

Energy is a scalar quantity that describes the current status of one or more objects and can take many forms.



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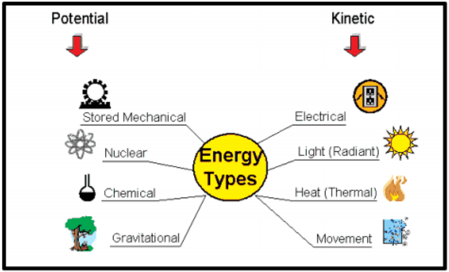
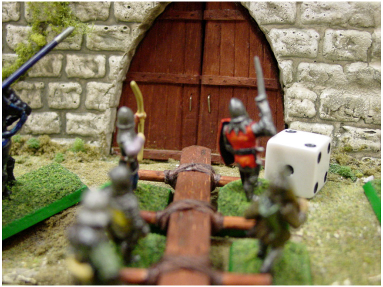


Energy is conserved but can transform from one type to another.

Kinetic Energy

Kinetic energy *is the energy of motion and is defined for an object to be*

$$K = \frac{1}{2}mv^2.$$



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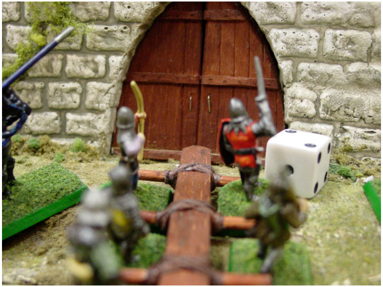
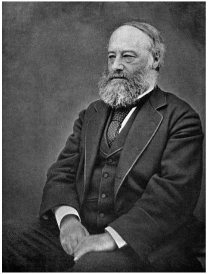


Heavier and faster objects carry more energy.

Kinetic Energy

The units of energy are (from mv^2) kg - m^2/s^2 which is given the name joule (J).



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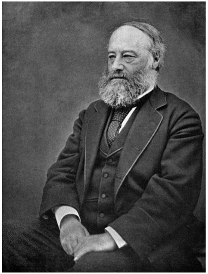


James Prescott Joule, not the Crowned Jewels.

Kinetic Energy

Lecture Question 7.1

To see why professional baseball pitchers are remarkable, determine the difference in the kinetic energy of a baseball thrown at speed v and one thrown at $2v$ and express the difference as a percentage [i.e., $(K_2 - K_1)/K_1 \times 100\%$].

(a) 50%

(b) 100%

(c) 200%

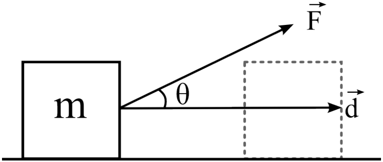
(d) 300%

(e) 400%

Work

Work W is defined as the amount of energy transferred to or from an object by means of a force.

$$W = \vec{F} \cdot \vec{d} = Fd\cos(\theta)$$



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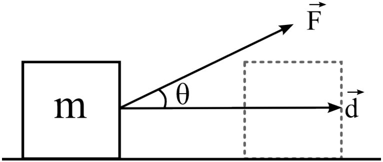
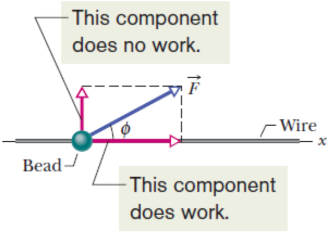


This is positive work; what would be negative?

Work

The scalar product indicates that only the component of $\vec{F}$ parallel to $\vec{d}$ matters.



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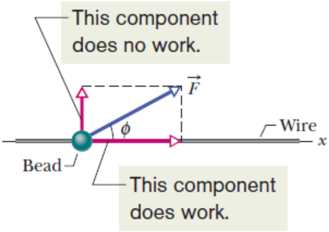
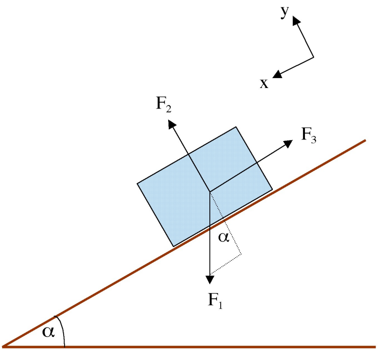


The component of the force perpendicular to the motion does no work.

Work

If two or more forces act on the object, the net work is the sum of the individual works done by each force.



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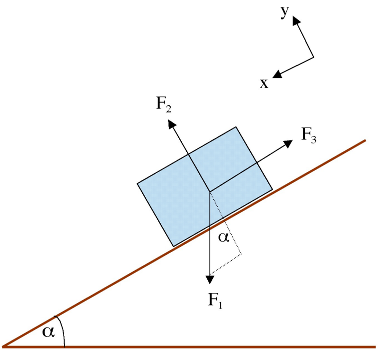

Remember: work can be zero or even negative.

Work

Work-kinetic energy theorem: *the change in kinetic energy of an object is equal to the net work done on that object.*

$$\Delta K = W_{net}$$

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Positive work gives an increase in KE; negative work gives a decrease in KE.

Lecture Question 7.2

Two wooden blocks (masses m and $2m$) are sliding with the same kinetic energy across a horizontal frictionless surface. The blocks then slide onto a rough horizontal surface. Let x_A be the distance that the light block slides before coming to a stop and x_B the distance that the heavy block slides before it stops. Then,

(a) $x_A = x_B$

(b) $x_A = 2x_B$

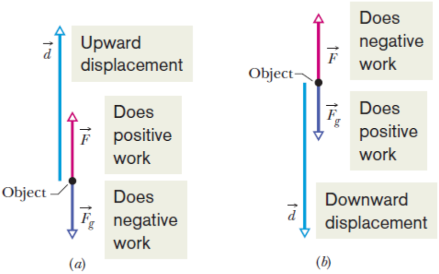
(c) $x_A = 4x_B$

(d) $x_A = 0.5x_B$

(e) $x_A = 0.25x_B$

Work Examples

Like all forces, gravity can do positive or negative work on an object.



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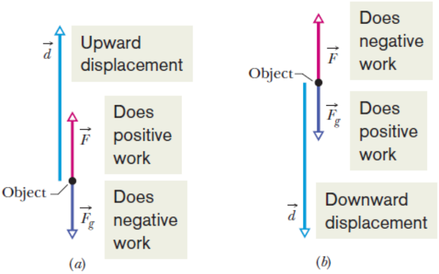
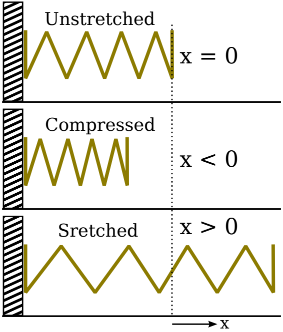


$$W_g = mgd\cos(\theta)$$

Work Examples

The force **from** *a spring is given by* $F_s = -kx$*,*
where k is the spring constant (stiffness) and x is how far the spring is stretched/compressed.



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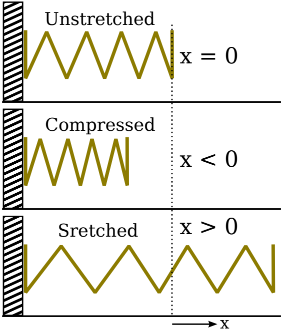
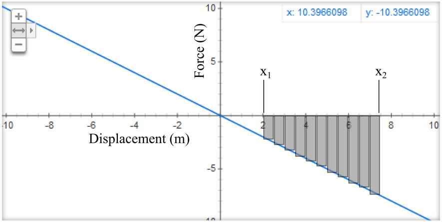


The force always points in the opposite direction of the displacement.

Work Examples

To find the work done by a variable force, we compute the work done over a small distance many times and then add them up.



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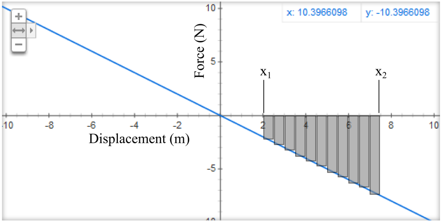

Each small amount of work is $\Delta W = F\Delta x$ or $dW = Fdx$.

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$$W = \int F(x)dx$$

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We compute the integral along a line of motion.

Work Examples

The work done by a spring is therefore:

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Work is positive if $x_1 > x_2$ (moves toward equilibrium)
Work is negative if $x_1 < x_2$ (moves away from equilibrium)

Work Examples

A general force:

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W &= \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot d\vec{r} \\
&= \int_{x_1}^{x_2} F_x dx + \int_{y_1}^{y_2} F_y dy + \int_{z_1}^{z_2} F_z dz
\end{aligned}$$

Power

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$$P = \frac{dW}{dt} \quad \text{or} \quad P_{avg} = \frac{W}{\Delta t}$$

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1 horsepower = 746 watts

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The instantaneous power is related to the velocity of an object:

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But in 3 dimensions,

$$P = \vec{F} \cdot \vec{v}$$

Power

Lecture Question 7.4

A car is accelerated from rest to a speed v in a time interval t. Neglecting air resistance effects and assuming the engine is operating at its maximum power rating when accelerating, determine the time interval for the car to accelerate from rest to a speed $2v$.

(a) 2t

(b) 4t

(c) 2.5t

(d) 3t

(e) 3.5t