Physics 1408-002
Principles of Physics

Lecture 12
– Chapter 7 & 8 –
February 19, 2009

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Announcement I

Lecture note is on the web
Handout (6 slides/page)
http://highenergy.phys.ttu.edu/~slee/1408/
*** Class attendance is strongly encouraged and will be taken randomly. Also it will be used for extra credits.

HW Assignment #5 will be placed on MateringPHYSICS today, and is due by 11:59pm on Wendseday, 2/25

The solutions for Exam 1 is available now;
Next to my office (Sci. 117)
The grades for Exam 1 is "DONE"

Announcement II

SI session by
Reginald Tuvilla

SI sessions will be at the following times and location.

Monday 4:30 - 6:00pm - Holden Hall 106
Thursday 4:00 - 5:30pm - Holden Hall 106

Chapter 7

Work & Energy

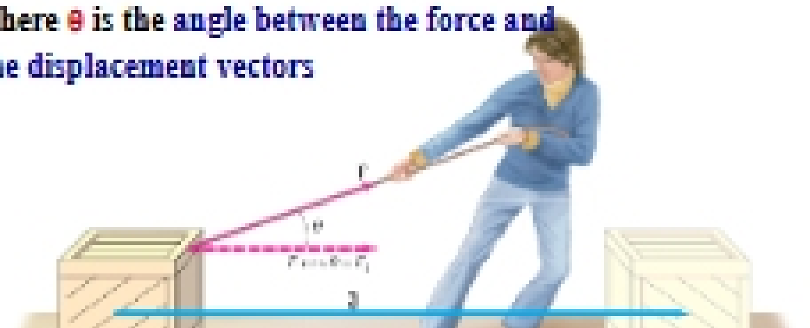
- Work Done (?) by a Constant Force
- Scalar Product of Two Vectors – Math.
- Work Done by a Varying Force
- Kinetic Energy and the Work-Energy Principle

7-1 Work Done by a Constant Force

The work done by a constant force is defined as the distance moved multiplied by the component of the force in the direction of displacement:

$$W = Fd\cos\theta.$$

where θ is the angle between the force and the displacement vectors



A person pulling a crate along the floor. The work done by the force F is W = Fd cos θ, where d is the displacement.

7-2 Scalar Product of Two Vectors

Definition of the scalar, or dot, product:

$$\vec{\mathbf{A}}\cdot\vec{\mathbf{B}} = AB\cos\theta$$

Therefore, we can write:

$$W = \vec{\mathbf{F}}\cdot\vec{\mathbf{d}} = Fd\cos\theta.$$

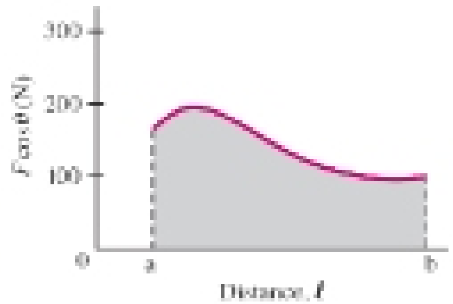
7-3 Work Done by a Varying Force

In the limit that the pieces become infinitesimally narrow, the work is the area under the curve:

$$W = \lim_{\Delta\ell_i \to 0} \Sigma F_i \cos\theta_i \, \Delta\ell_i = \int_a^b F \cos\theta \, d\ell.$$

or:

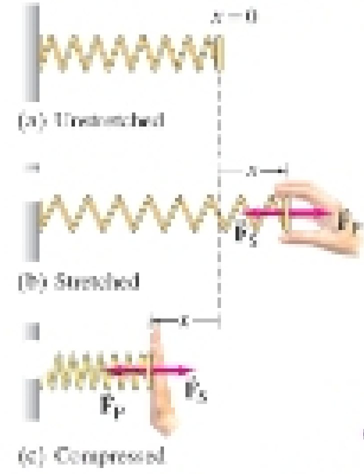
$$W = \int_a^b \vec{\mathbf{F}} \cdot d\vec{\ell}.$$



Work = Area under Fcosθ curve

7-3 Work Done by a Varying Force

Work done by a spring force:



The force exerted by a spring is given by:

$$F_S = -kx$$

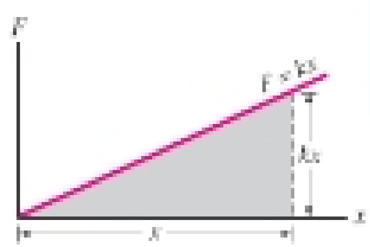
x = the position of the block with respect to the equilibrium position ($x = 0$)

k = the spring constant and measures the stiffness of the spring

- This is called Hooke's Law

(a) Spring in normal (unstretched) position. (b) Spring is stretched by a person exerting a force F_P to the right. The spring pulls back with a force F_S where $F_S = -kx$. (c) Person compresses the spring ($x < 0$) and the spring pushes back with a force $F_S = kx$ where $F_S > 0$ because $x < 0$.

7-3 Work Done by a Varying Force



Plot of F vs. x. Work done is equal to the shaded area.

$$W = \int_a^b \vec{\mathbf{F}} \cdot d\vec{\ell}.$$

$$W_P = \int_{x_a=0}^{x_b=x} [F_P(x)\,\hat{\mathbf{i}}] \cdot [dx\,\hat{\mathbf{i}}] = \int_0^x F_P(x)\,dx$$

$$= \int_0^x kx\,dx = \tfrac{1}{2}kx^2 \Big|_0^x = \tfrac{1}{2}kx^2$$

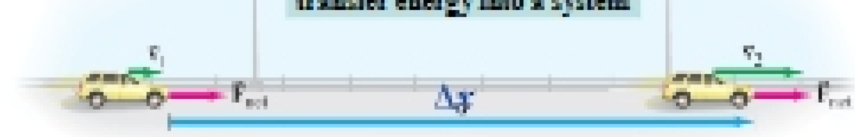
Work done to stretch a spring a distance x equals the triangular area under the curve $F = kx$. The area of a triangle is ½ x base x altitude, so $W = ½(x)(kx) = ½ kx^2$.

7-4 Kinetic Energy and the Work-Energy Principle

- $v_2^2 - v_1^2 = 2a(x_2 - x_1) = 2a\Delta x$
- multiply by $\frac{1}{2}m$: $\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = ma\Delta x$
- But $F = ma$ $\quad \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = F\Delta x$
- $\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = F\Delta x = W_{net} = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2.$

- **We define Kinetic Energy** $\quad K = \frac{1}{2}mv^2.$
  - $K_2 - K_1 = W_{net}$
  - $W_{net} = \Delta K$ **(Work/kinetic energy theorem)**

A change in kinetic energy is result of doing work to transfer energy into a system



7-4 Kinetic Energy and the Work-Energy Principle

This means that the **work** done is equal to the **change** in the kinetic energy:

$$W_{net} = \Delta K = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2.$$

- If the net work is **positive**, the kinetic energy **increases**.
- If the net work is **negative**, the kinetic energy **decreases**.

Example 7-7: Kinetic energy and work done on a baseball.

A 145-g baseball is thrown so that it acquires a speed of 25 m/s.

(a) What is its kinetic energy?

(b) What was the net work done on the ball to make it reach this speed, if it started from rest?

SOLUTION (a) The kinetic energy of the ball after the throw is

$$K = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(0.145\,\text{kg})(25\,\text{m/s})^2 = 45\,\text{J}.$$

(b) Since the initial kinetic energy was zero, the net work done is just equal to the final kinetic energy, 45 J.

Example 7-8: Work on a car, to increase its kinetic energy.

How much net work is required to accelerate a 1000-kg car from 20 m/s to 30 m/s?

$v_1 = 20\ \mathrm{m/s}$ $\qquad$ $v_2 = 30\ \mathrm{m/s}$

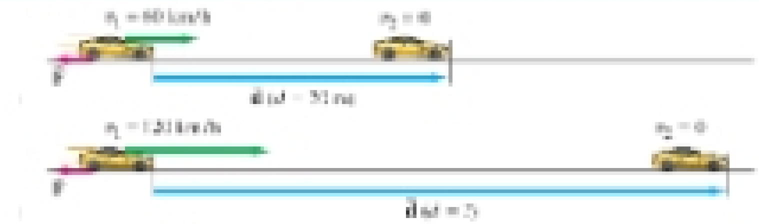
SOLUTION The net work needed is equal to the increase in kinetic energy:

$$W = K_2 - K_1 = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2$$
$$= \tfrac{1}{2}(1000\ \mathrm{kg})(30\ \mathrm{m/s})^2 - \tfrac{1}{2}(1000\ \mathrm{kg})(20\ \mathrm{m/s})^2 = 2.5 \times 10^5\ \mathrm{J}.$$

The net work is the increase in kinetic energy, 2.5×10^5 J.

Example 7-9: Work to stop a car.

A car traveling 60km/h can brake to a stop within a distance of 20 m. If the car is going twice as fast, 120 km/h, what is its stopping distance? Assume the maximum braking force is approximately independent of speed.



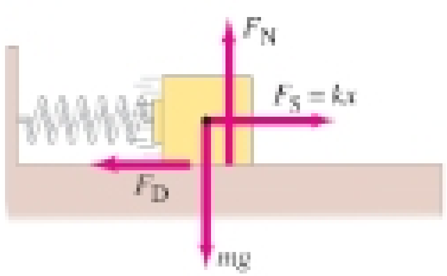
$$W_{net} = Fd\cos 180^\circ = -Fd.$$
$$-Fd = \Delta K = \tfrac{1}{2}mv_2^2 - \tfrac{1}{2}mv_1^2$$
$$= 0 - \tfrac{1}{2}mv_1^2.$$

The stopping distance increases as the square of the speed (as does the force needed to stop), so it will take 80 m.

Example 7-10: A compressed spring.

A horizontal spring has spring constant $k = 360$ N/m.

(a) How much work is required to compress it from its uncompressed length ($x = 0$) to $x = 11.0$ cm?

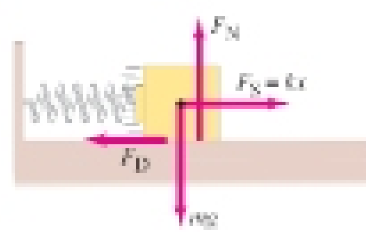


$$W = \tfrac{1}{2}(360\ \mathrm{N/m})(0.110\ \mathrm{m})^2 = 2.18\ \mathrm{J}$$

Example 7-10: A compressed spring.

A horizontal spring has spring constant $k = 360$ N/m.

(b) If a 1.85-kg block is placed against the spring and the spring is released, what will be the speed of the block when it separates from the spring at $x = 0$? Ignore friction

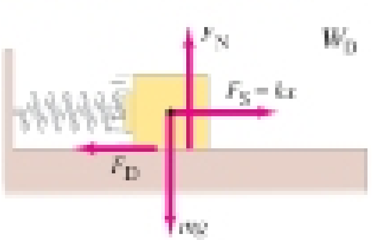


$$v = \sqrt{\frac{2K}{m}}$$
$$= \sqrt{\frac{2(2.18\ \mathrm{J})}{1.85\ \mathrm{kg}}} = 1.54\ \mathrm{m/s}$$

Example 7-10: A compressed spring.

A horizontal spring has spring constant k = 360 N/m.

(c) Repeat part (b) but assume that the block is moving on a table and that some kind of constant drag force F_D = 7.0 N is acting to slow it down, such as friction (or perhaps your finger).



$$W_D = -F_D x = -(7.0\ \mathrm{N})(0.110\ \mathrm{m}) = -0.77\ \mathrm{J}$$
$$W_{net} = 2.18\ \mathrm{J} - 0.77\ \mathrm{J} = 1.41\ \mathrm{J}$$
$$v = \sqrt{\frac{2W_{net}}{m}}$$
$$= \sqrt{\frac{2(1.41\ \mathrm{J})}{1.85\ \mathrm{kg}}} = 1.23\ \mathrm{m/s}$$

Definition of Work

$$W = \int \vec{F} \cdot \vec{dr}$$

$$W = \int F_x dx \qquad \text{One Dimension}$$

$$W = \vec{F} \cdot \vec{\Delta r} \qquad \text{Constant Force}$$

Definition of Kinetic Energy

$$K = \tfrac{1}{2}mv^2$$