PHYS 1901 – Physics 1A (Advanced) Mechanics module

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Work and Kinetic Energy

Chapter

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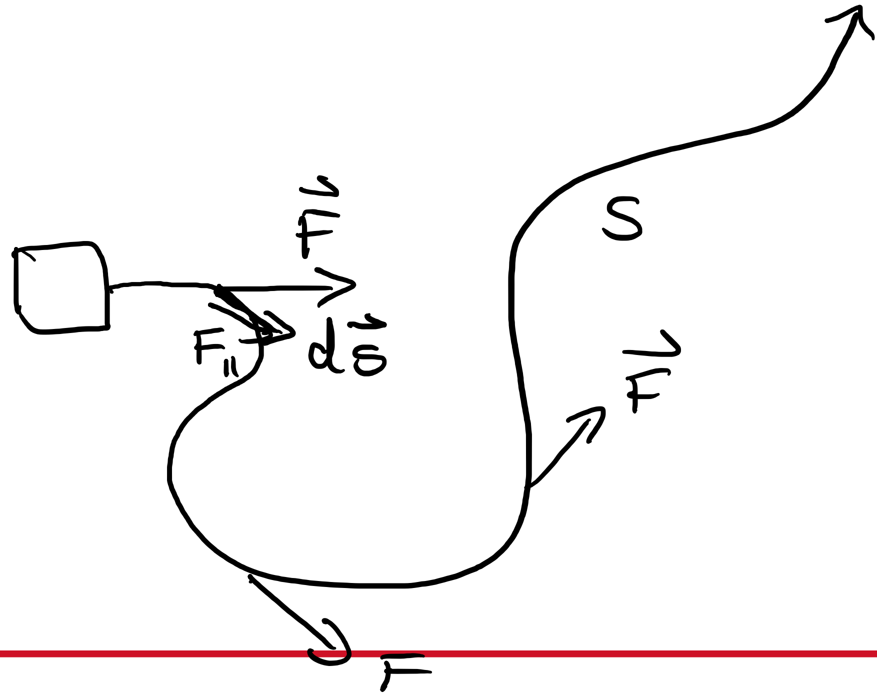
Work and Kinetic Energy

The concept of *work* can be understood when a force is applied to a body to change its motion

Work is done *on an object* when a force changes its point of application and is defined to be:

$$W = \int_i^f F_{\parallel}\, ds$$
$$= \int_i^f \vec{F} \cdot d\vec{s}$$



What is the dot? (Section 1.10)

The *dot product* allows us to multiply two vectors;

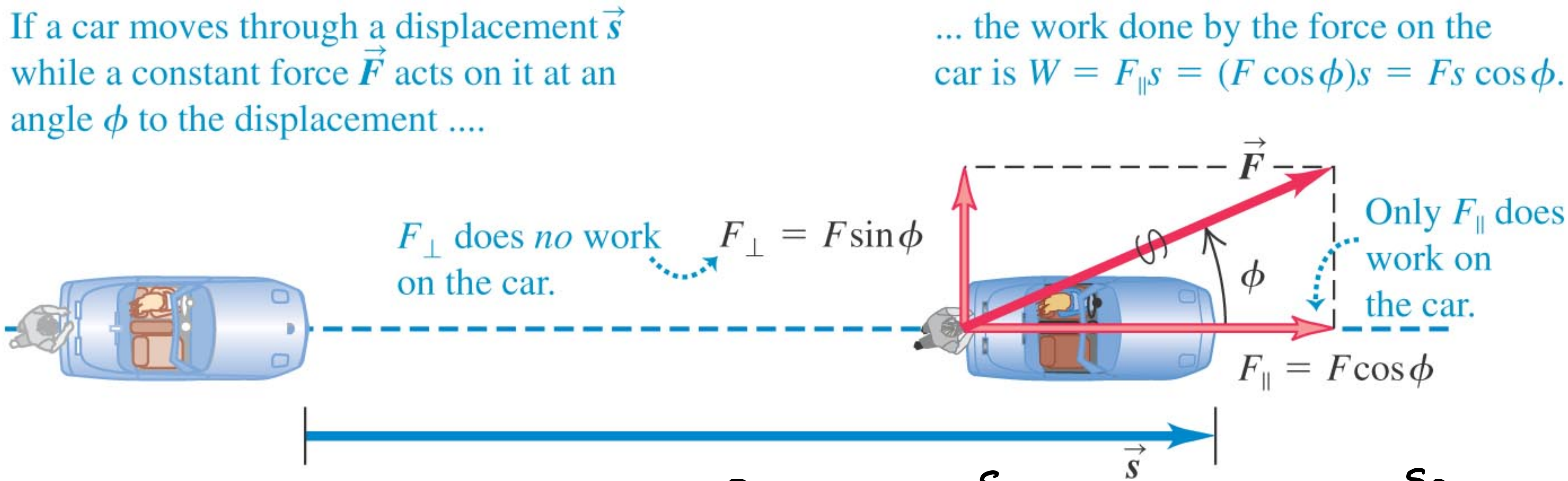
$$\vec{A} \cdot \vec{B} = |\vec{A}|\,|\vec{B}| \cos\phi$$

Given the components of a vector, the dot product is simple to calculate;

$$\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$$

Work is a **scalar!**

Why the dot?



$s = |\vec{s}| = s_f - s_i$

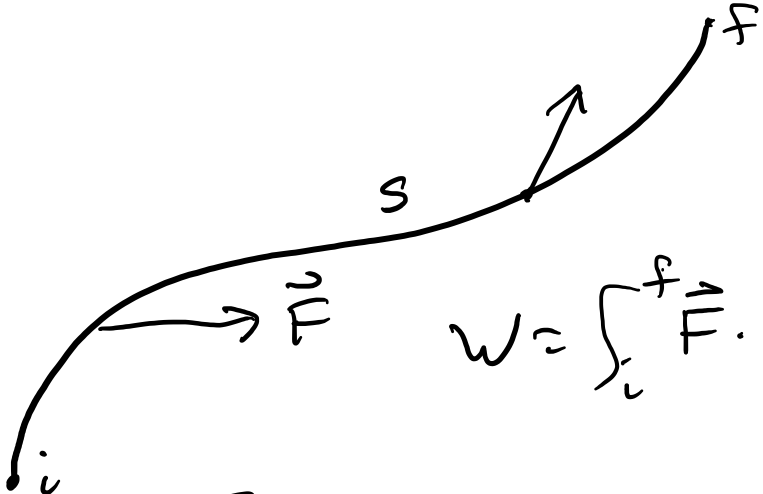
For a constant force; $W = \int_i^f \vec{F}\cdot d\vec{s} = \int_{s_i}^{s_f} F\cos\phi \, ds = F\cos\phi \int_{s_i}^{s_f} ds = F s \cos\phi$

Only the force in the direction of motion contributes to the work done on an object. This is *selected* by the dot product.

Work has units of **N m** which equals Joules (i.e. it is energy)

Kinetic Energy, and the Work-Energy Theorem

$K_f = \frac{1}{2} m v_f^2$



Define the kinetic energy

$$K = \frac{1}{2} m v^2$$

$$W = \int_i^f \vec{F} \cdot d\vec{s}$$

It is a scalar quantity (like work)

From the kinematic equations;

$$K_f - K_i = \Delta K = W \qquad K_i = \frac{1}{2} m v_i^2$$

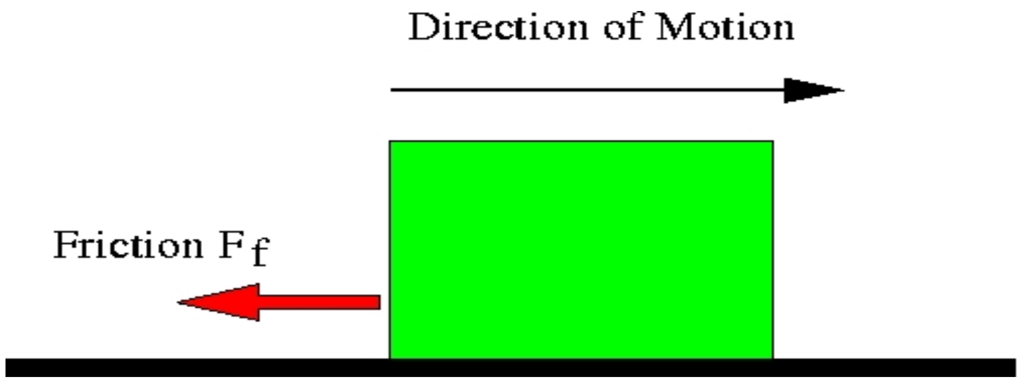
work done by net force

A force acting on a body results in a change of kinetic energy. This is known as the **Work-Energy Theorem**.

Negative Work

v_i $\qquad$ $v_f = 0$

$s_i = 0$ $\qquad$ s_f

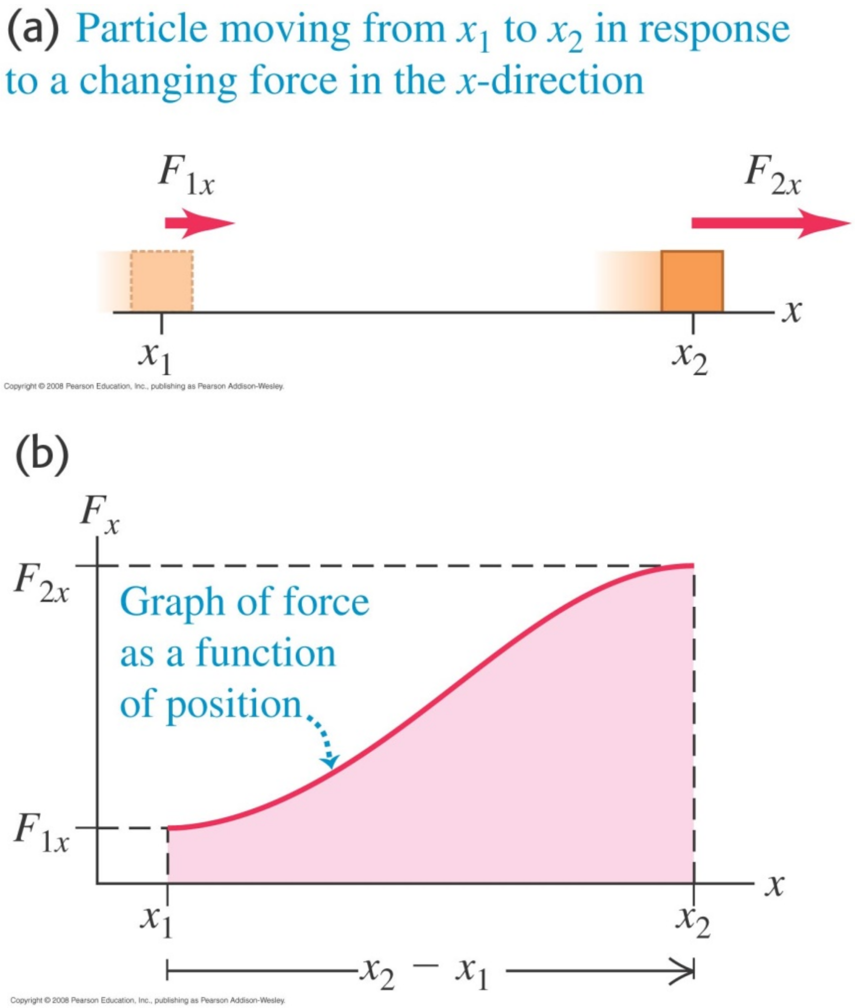


Friction opposes the direction of motion *(ϕ=180)*

$$W = \int_i^f \vec{F}\cdot d\vec{s} = \underbrace{\vec{F}}_{\text{constant force}}\cdot\vec{s} = -|F_f|\,|s| \quad \text{(negative)}$$

Negative work done on an object reduces the amount of kinetic energy it has.

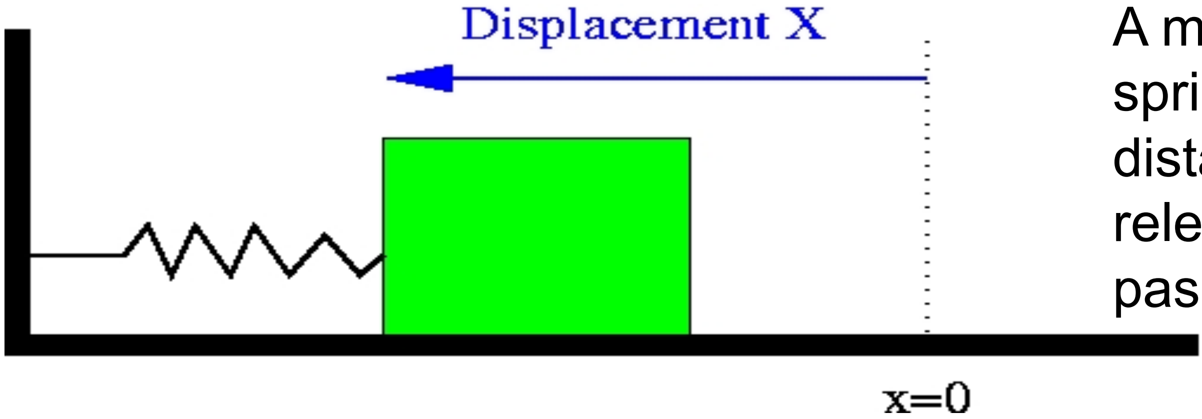
Using energy



Calculating the work done by a variable force is equivalent to area under the force-distance curve along the path of the object.

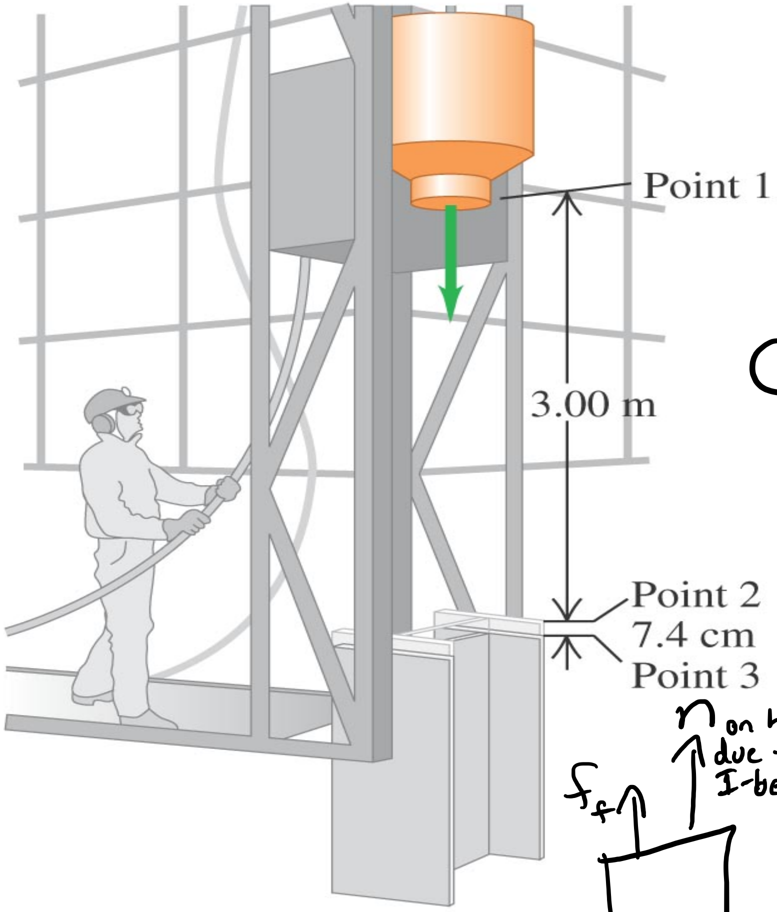
This can be much simpler than dealing with vectors.

Example: a spring



A mass is pushed up against a spring, compressing it by a distance *X*. The mass is then released. What is its velocity as it passes through *x=0*?

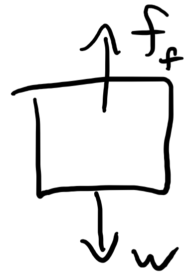
Example 6.4



Hammerhead: 200kg, 3m above ground

Drives I-beam 7.4cm deeper

Vertical rails: 60 N constant friction force



Find the average force the hammerhead exerts on the I-beam

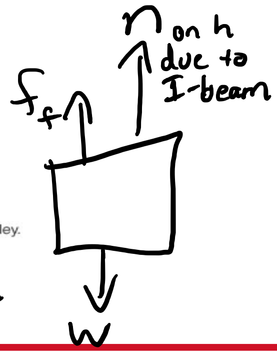
① Hammerhead falls from point 1 to 2

$F_{net} = w - f_f = (200\text{kg})(9.8\,\text{m/s}^2) - 60\text{ N}$

$= 1900\text{ N}$

$W = \vec{F}_{net} \cdot \vec{s} = F_{net} \times s = (1900\text{N})(3\text{m}) = 5700\text{ J}$

$\Delta K_{1\to2} = W \qquad K_2 = 5700\text{ J}$



$F_{net} = w - f_f - n$ (a neg number)

② $\Delta K_{2\to3} = -5700\text{ J} = W = F_{net}(7.4\text{cm})$

$-5700\text{J} = [1900\text{ N} + n](0.074\text{ m})$

Solve for $n = -7.5 \times 10^4\text{ N}$

So force on beam is $7.5\times10^4\text{ N}$ down