Thurs: Discussion Quiz

Ex 213, 214, 216, 217, 218, 219

Fri: Usual

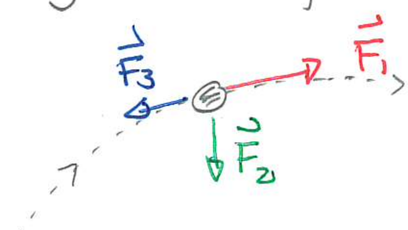
Mon: Next HW

Work and energy

The concept of energy will allow for alternative, often simpler, methods to analyze motion and mechanical systems. The crucial link between the language of forces and that of energy is work. Intuitively

> work ~ extent to which a force succeeds in increasing speed

We can consider various forces acting on an object as it moves. For the illustrated forces



$\vec{F}_1$ ⟶ tends to make object speed up.

$\vec{F}_2$ ⟶ tends to make it curve

$\vec{F}_3$ ⟶ " " make object slow down

These tendencies are related to the direction of the force and also the direction of motion. Work will incorporate both. We will:

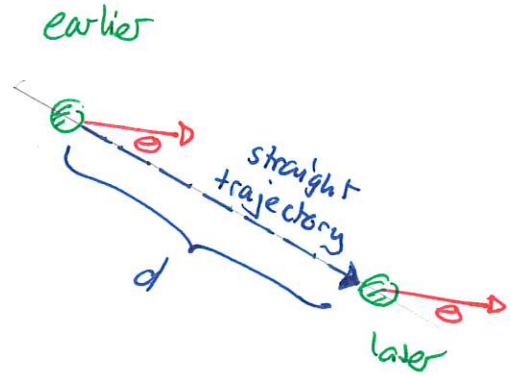
* First, define work for the situation where the object moves in a straight line and force is constant.

* Then, extend to more general situations.

In the restricted case:

Suppose that

* the object moves along a straight line
* a constant force acts on the object at all moments between an earlier and later instant.



Then the work done by the force is

$$W = Fd\cos\theta$$

where F = magnitude of force (not negative)

d = distance traveled (not negative)

θ = angle between direction of motion and force

Units: Joules

$J = N \cdot m$

Quiz 1 50% - 100%

The work done can be positive, negative or zero. This depends on the angle between the force and displacement.

Angle between force and direction of motion	$\cos\theta$	work	affect of force on speed
$\theta = 0$	+1	+	speed up
$0 \leq \theta < 90°$	positive	positive	" "
$\theta = 90°$	0	0	no change in speed
$90° < \theta < 180°$	negative	negative	slow down
$\theta = 180°$	−1	negative	" "

Quiz 2 30% - 100%

Warm Up 1

Net work.

In general there may be many forces acting on an object. In such cases we can do the following

Force 1 ⇝ produces work W_1

Force 2 ⇝ " " W_2

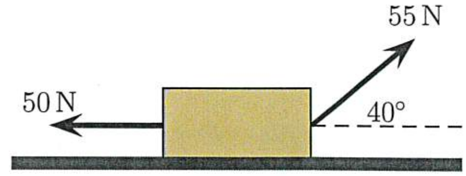
⋮

Then

The total (net) work done on the object = sum of the work done by each force

215 Tugging on a box

A 6.0 kg box moves 8.0 m to the right along a horizontal frictionless surface. Alice pulls left on the crate with a 50 N force as illustrated. Bob pulls right with a 55 N force, angled as illustrated. *(111F2023)*



a) Determine the work done by Alice on the box.

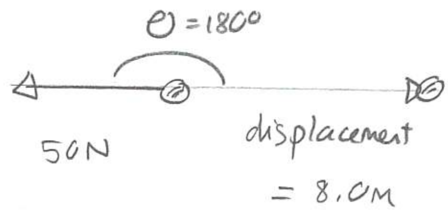
b) Determine the work done by Bob on the box.

c) Determine the net work done on the box.

Answer: a) $W_A = Fd\cos\theta$

$= 50N \times 8.0m \cos 180^\circ$

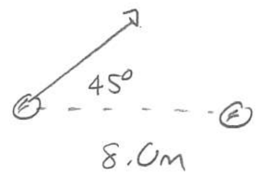
$= -400J$



b) $W_B = Fd\cos\theta$

$= 55N \times 8.0m \cos 40^\circ$

$= +337J$



c) There are two other forces: normal and gravity

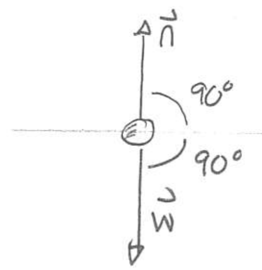
In each case

$W = Fd\cos\theta$

and $\theta = 90^\circ \Rightarrow \cos\theta = \cos 90^\circ = 0$

Thus $W_{grav} = 0J$

$W_{normal} = 0J$



The net work is $W_{net} = W_A + W_B + W_{grav} + W_{normal}$

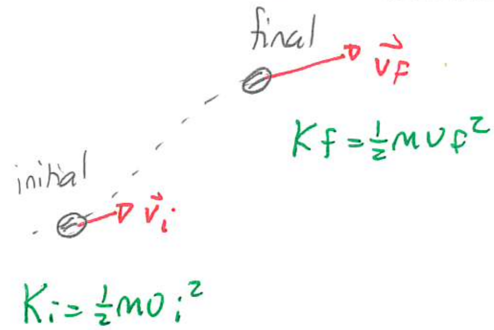
$= -400J + 337J + 0J + 0J$

$= -63J$

In this example, an analysis of the forces would show that the net force is left. So the acceleration is left and the object slows. This can be rephrased in terms of work via:

> The kinetic energy of an object with mass m moving with speed v is
>
> $$K = \frac{1}{2} m v^2$$
>
> 
>

Then one can prove mathematically that:

> Consider an object moving from an initial to final instant. Then
>
> $$W_{net} = \Delta K = K_f - K_i$$
>
> 
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This is the work-kinetic energy theorem. For the example above

W_{net} is negative $\Rightarrow$ $K_f < K_i$

$$\Rightarrow \frac{1}{2} m v_f^2 < \frac{1}{2} m v_i^2$$

$$\Rightarrow v_f < v_i$$

and the object slows down

Warm Up 2