Announcements **Lecture 9: Tues, 30 Sep 2008**

1. All Friday HW assignments now due Saturday nights

2. Reminder: Email from TA about free-body diagrams

Work

Demo: Moving a cart

Clicker quiz: Who did the most work?
- a) the one who lifted the cart
- b) the one who moved the cart horizontally
- c) same work done

Definition of work in physics:

$$\mathbf{W = F_{//}\Delta x}$$

(not a vector!)

The work done by a force on an object is the component of the force along the direction of motion times the magnitude of the object's displacement.

Disclaimer: only true for constant forces, otherwise you need calculus

SI Units: 1 N × 1 meter = 1 Joule

Recall: 1 N = 1 kg m/s^2 … units start getting pretty complicated

Positive vs. Negative

Positive if force is in line with motion
→ adds "energy" to system

Negative if force is opposite the motion
→ removes energy from system

Zero if force is perpendicular to the path
→ leaves energy unchanged

What is energy?

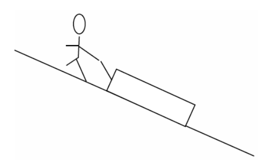
Wikipedia: "The ability to do work…"
→ Think football players

Kinetic energy

Definition: An object's ability to do work that is inherent in its motion.

$$KE = \tfrac{1}{2} m v^2$$

A girl pulls a sled up a hill at constant speed.



For the following forces, decide if the work is …
- a. positive
- b. negative
- c. zero

Non-clicker Question: The girl's force on the sled?

Clicker quiz: Friction?
Clicker quiz: The force of gravity on the sled?
Clicker quiz: The sled's force on the girl?
Clicker quiz: The normal force on the sled?

Why use work/energy?

→ It is easier!

Some problems that are hard using Newton's 2nd law can be worked **easily** with energy ideas, if you don't need to know _______!

Law of conservation of energy

$$E_{before} + W = E_{after}$$

aka "Work-Energy theorem"

Worked Problem

A 5 gram bullet smashes through a thin board. It's traveling at 100 m/s when it hits the board, but only at 80 m/s when it emerges from the other side. (a) How much work did the board do in slowing the bullet? (b) If the board is 1 cm thick, what average force did the board exert on the bullet?

Old way:

- Find acceleration of bullet using a kinematics eqn
- Use Newton's 2nd Law to find the force
- Find the work via definition $W = F_{//}\Delta x$

New way:

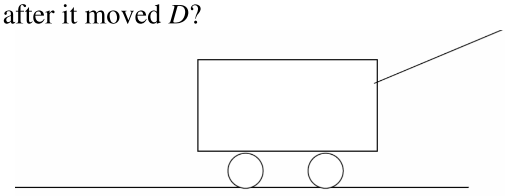
- Find E_{before} and E_{after}
- Use the Law of Conservation of Energy to find work
- Find the force using $W = F_{//}\Delta x$

The "miracle": They give you the same answer!!

Worked Problem

A boy pulls his toy **mass m** with a **force P**, at an **angle** θ above the horizontal. He moves the toy a **distance *D*** along the ground without friction.

If the initial velocity of the toy was v_0, how **fast** was it going after it moved D?



Method 1. Conservation of energy

Method 2: Newton's laws and kinematic eqns.:
→ have to use if we want to know **time it took**

You pull on a 60 kg load with a force of 80 N at an angle 30 degrees above horizontal. It starts from rest, and after traveling 12 meters, it's going 3 m/s. There is also some work done by friction.

Clicker quiz: The net work done on the wagon was

a. positive
b. negative
c. zero

Clicker quiz: What work did you do on the wagon? (From *your* force)

a. 0-100 J
b. 100-200
c. 200-300
d. 300-400
e. 400+

Clicker quiz: What was the net work done by **all** the forces on the wagon? (Hint: from change in KE)

a. 0-100 J
b. 100-200
c. 200-300
d. 300-400
e. 400+

Question: Then what was the work done by friction on the wagon?

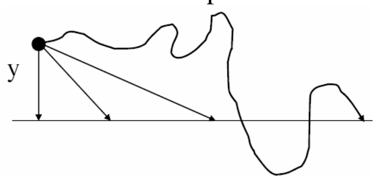
Gravitational potential energy

$PE_{gravity}$ *keeps track* of the ____________ done against gravity

Formula: $PE_g = mgy$

(compare: work = force × distance)

Change in PE for the different paths?



"Conservative" vs. "nonconservative" forces:

Video: Triple Track
Demo: Duckpin ball pendulum

Work-Energy theorem, revisited

$E_{before} + W = E_{after}$

"Law of conservation of energy"

Statement one:

$KE_{bef} + W = KE_{aft}$

W must include work done by *all* forces

Statement two:

$KE_{bef} + PE_{bef} + W = KE_{aft} + PE_{aft}$

W only includes work by *nonconservative* forces

Both cases: W can be positive or negative

Video: pole vaulter

"Energy cannot be created or destroyed, only changed from one form into another…" [*mostly* true]

Simple Analysis: How high can pole jumpers jump?

Compare:
Top velocities: ~11 m/s for short distances
Pole vault world record: 6.14 m

Problem: From a cliff of height *h* you throw balls straight up, straight down and horizontally, all with the *same initial speed.*

Clicker quiz: Ignoring air friction, which ball has the highest speed just before it hits the ground?

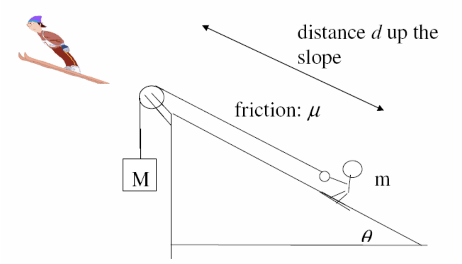
a. thrown straight up
b. thrown straight down
c. thrown horizontally
d. all the same speed

Clicker quiz: If you include air friction, then which one has the highest speed just before it hits the ground?

a. thrown straight up
b. thrown straight down
c. thrown horizontally
d. all the same speed

Pulley ski jumping, revisited

What is the speed just at takeoff?



Old way: find *a* via N2; then use kinematic formulas. Yuck!

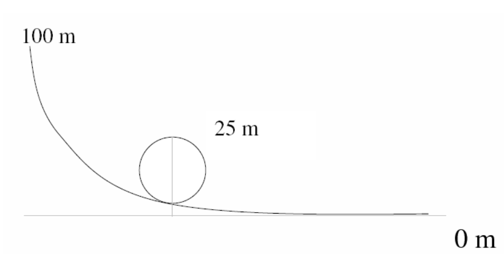
New way:

Demo: Vertical Cannon Cart with track

Demo problem: You hang a _____ kg mass from a pulley and attach it to a ______ kg cart with a string. You let the hanging mass fall ______ m. How fast it is going at the end?

Clicker quiz: A 500 kg car starts from rest on a track 100 m above the ground. It does a loop-de-loop that is 25 m from the ground at the top. There is no friction. How fast is it going at the *top* of the loop?

a. 0-10 m/s
b. 10-20
c. 30-40
d. 40-50
e. 50+ m/s



Depends on mass?