Announcements – 26 Sep 2013

1. **Exam 2 is coming up!**
   a. Exam 2 begins one week from today (Thurs), runs through the following Wednesday, 2 pm (late fee after 2 pm Tuesday)
   b. Thursday will be exam review, whole lecture
   c. Covers Chapters 4 & 5, Homeworks 5-9
      → HW 9 due on Thurs night

2. **TA evening exam review session** either Wed or Thursday
   a. I will send out link to poll, like I did last time

Shawn said he can't do Wednesday

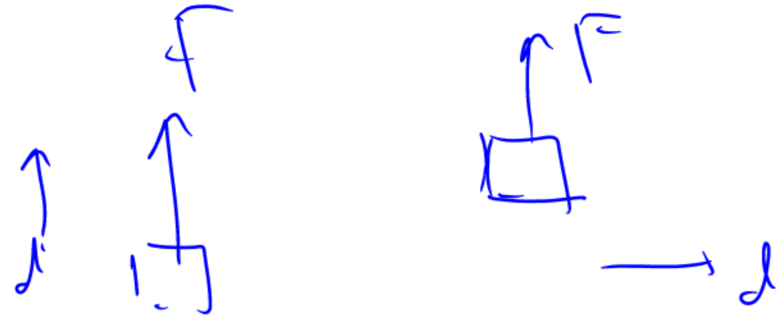
New topic: Work and Energy

Demo: Moving a cart at constant velocity

Question: 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



$$W = F_{//} d$$

(not a vector!)

The work done **by a force** **on an object** is the component of the force along the direction of motion ("$F_{//}$") times the magnitude of the object's displacement.

Units of work?

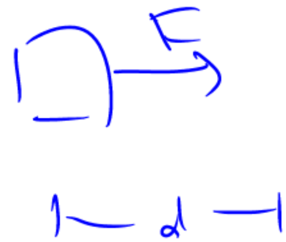
= force x distance

= N · m

= "joule", J

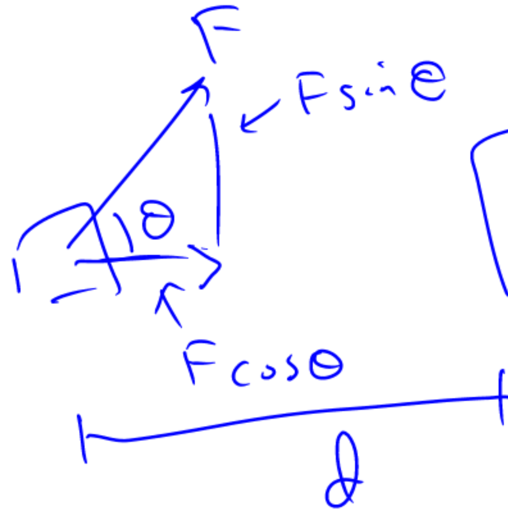
$$W = F_{//} d$$

What if **F** is in line with **d**?



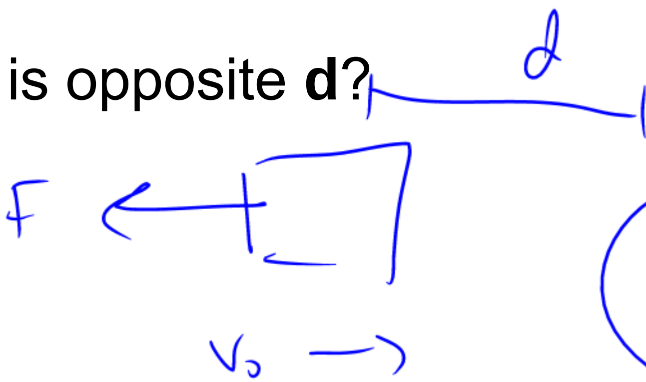
$W = Fd$

What if **F** is at an angle θ away from **d**?



$W = (F\cos\theta) d$

What if **F** is opposite **d**?



$W = -Fd$

What if **F** is not constant?

use F_{ave}

From warmup

When you carry an object across the room, without lifting it or setting it down, you do no "mechanical work" on it.

a. true
b. false

You need to carry a suitcase up a flight of stairs. In which case will you do the most mechanical work?

a. You carry the suitcase up quickly.
b. You carry the suitcase up slowly.
c. Both cases involve the same amount of work.

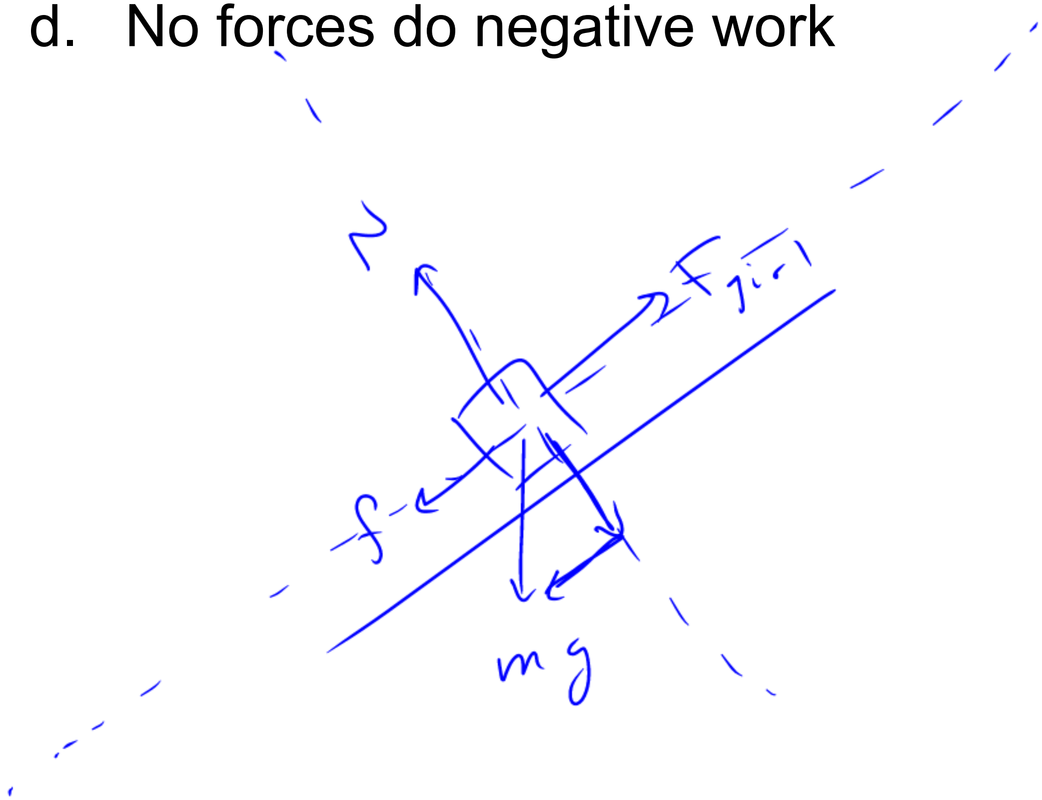
The amount of potential energy possessed by an elevated object is equal to

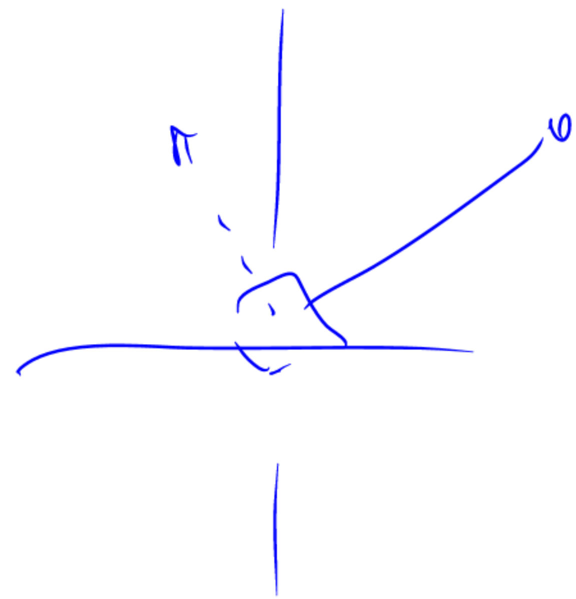
a. the distance it is lifted
b. the force needed to lift it
c. the work done in lifting it
d. its acceleration due to gravity

Clicker quiz

A girl pulls a sled up a hill at constant speed. Which forces do negative work on the sled?

a. Friction only
b. Friction and gravity
c. Friction, gravity, and the normal force
d. No forces do negative work





From warmup

According to the reading assignment, a car coasting from rest down two hills, one steeper than the other, would arrive at the bottom of each hill with the same speed, as long as the two hills have the same vertical height. (Of course, this is true only if we neglect friction and air resistance.) This confuses Ralph, since he realizes that the acceleration of the car down the steep hill will be greater than down the other hill. What should you tell him to help clear this up?

"Pair share"–I am now ready to share my neighbor's answer if called on.

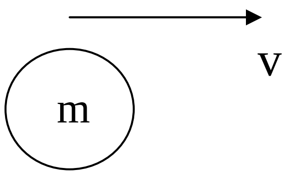
a. Yes

Kinetic Energy

Defn: Object's ability to do work that comes from its motion.

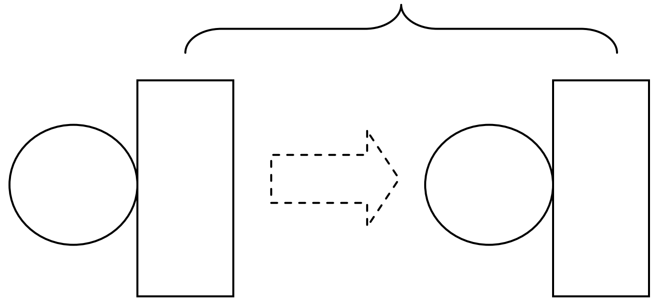
$$KE = \frac{1}{2} m v^2$$

Derivation:



Ball in motion, sticks to block

Ball pushes fictitious block a distance Δx



Block provides constant stopping force F → $a = -\frac{F}{m}$

What is Δx? Use Kinematics… $v_f^{\,2} = v_0^{\,2} + 2a\Delta x$

$$0 = v^2 + 2\left(-\frac{F}{m}\right)\Delta x$$

$$\Delta x = \frac{mv^2}{2F}$$

How much work does the object do as it stops?

$$W = F\Delta x$$

$$= F\left(\frac{mv^2}{2F}\right)$$

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

Why use work/energy?

→ It is often easier!

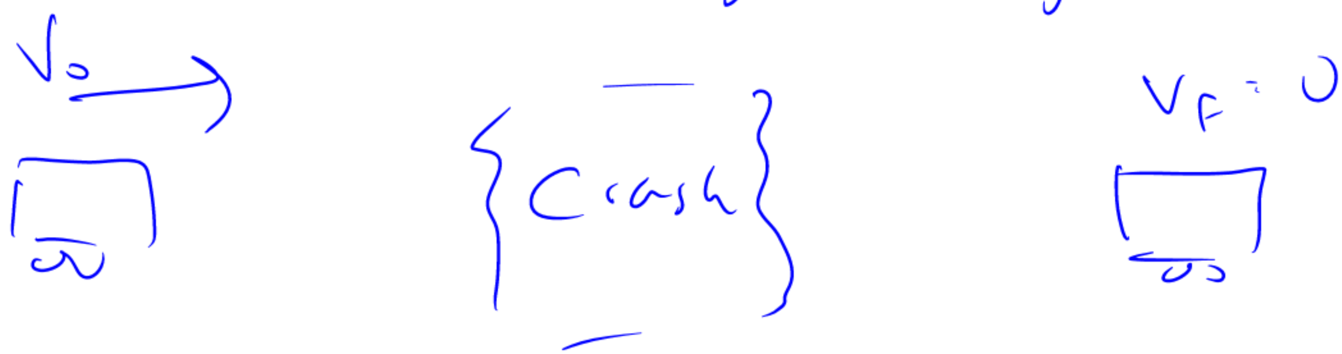
Some problems that are hard using Newton's 2nd law can be worked **easily** with energy ideas, if you don't need to know the time!

Law of Conservation of Energy

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

aka “Work-Energy theorem”

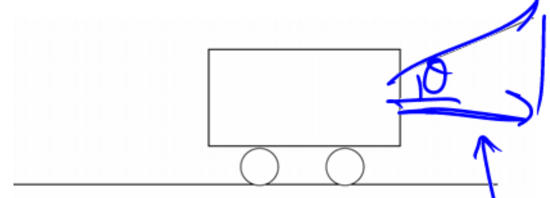
Blueprint!!



Problem solving hint:
Always draw “before” and “after” pictures. Maybe also draw a FBD for the "between" section if there are forces doing work.

Worked problem

A boy pulls his toy **mass m** with a **force P**, at an **angle** θ above the horizontal. The toy has an initial velocity of $\boldsymbol{v_0}$. Disregard friction.

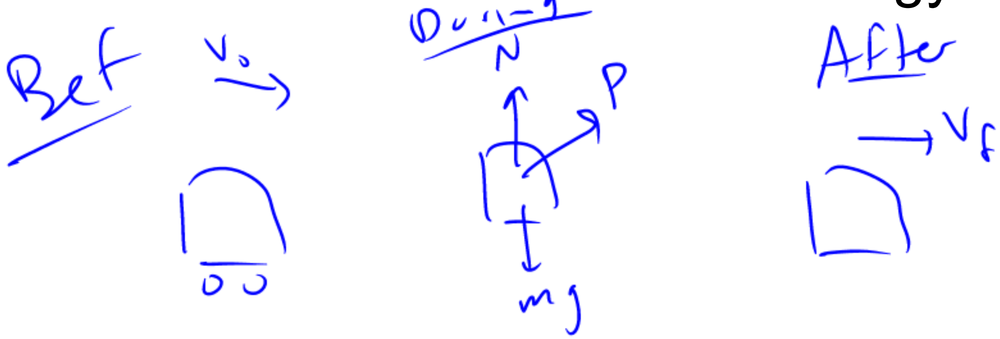


How **fast** is the toy going after the boy pulls it a distance D?

Method 1: The old way

a. Use N2 to figure out acceleration
b. Use kinematics equations to figure out final speed, time, or whatever is wanted.

Method 2. Conservation of energy

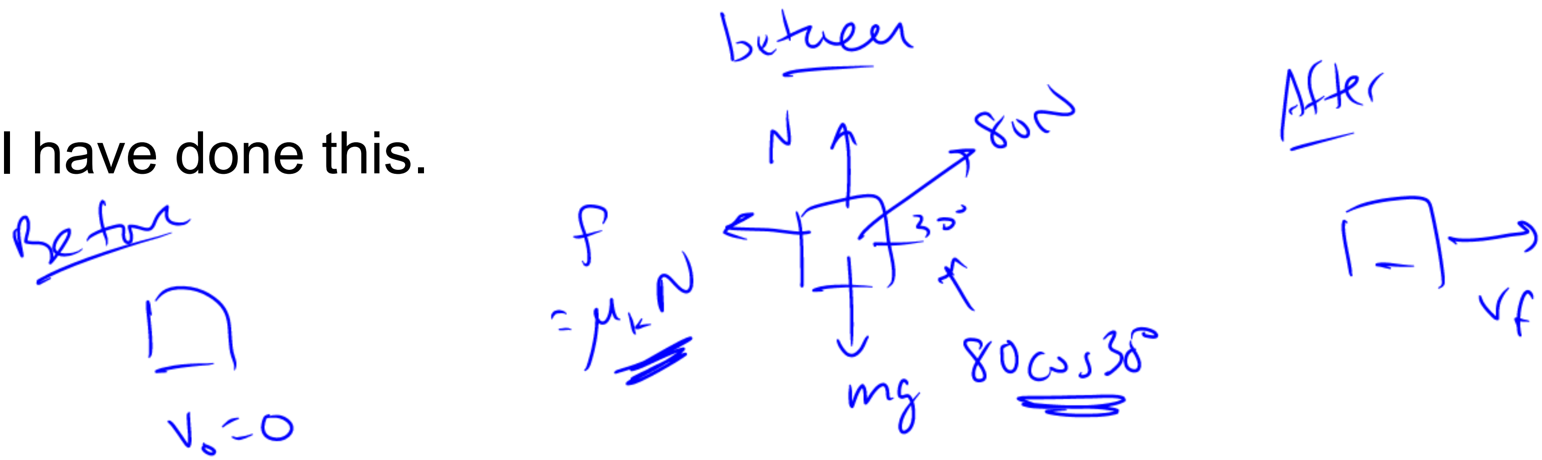


Answer: $\sqrt{v_0^{\,2} + \dfrac{2PD\cos\theta}{m}}$

Worked problem

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. Use g = 10 m/s^2. What is μ_k?

Step 1: Draw before and after pictures, and a FBD for the in-between part.



Clicker quiz 1: I have done this.

a. yes
b. no

Clicker quiz 2: How many terms need to be part of the "work" part of the conservation of energy equation?

a. 0
b. 1
c. 2
d. 3
e. 4

$E_{bef} + W_{net} = E_{aft}$

Step 2: Write down the blueprint equation

Clicker quiz: I have done this.

a. yes
b. no

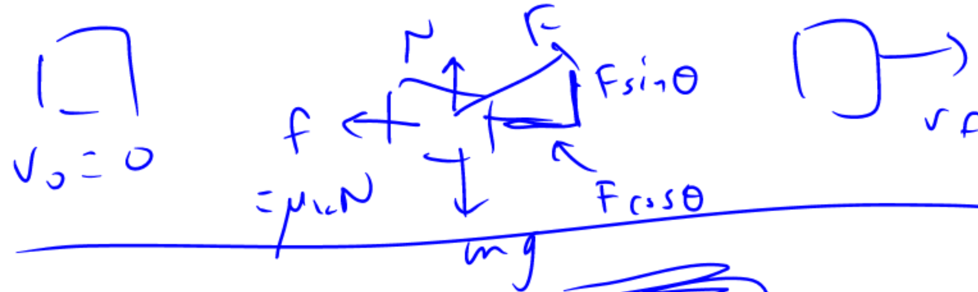
$m = 60$ $F_{pull} = 80\,N$ $\theta = 30°$ $d = 12\,m$ $v_0 = 0$ $v_f = 3\,m/s$ $g = 10\,m/s^2$

Step 3: Fill in the blueprint as much as you can (using letters)

Clicker quiz: I have done this.

a. yes
b. no

$E_{bef} + W_{net} = E_{aft}$



$W = F_{\parallel} d$

$$0 + (F_{pull}\cos\theta)d - (\mu_k N)d = \frac{1}{2}mv_f^2$$

→ **What do you do about the unknown normal force?**

Step 3b: Think about terms in the blueprint that you don't know

$\Sigma F_y = 0$

$N + F_{pull}\sin\theta - mg = 0$

$N = mg - F_{pull}\sin\theta$

$(80\cos 30)(12) - \mu_k(60\cdot 10 - 80\sin 30°)12 = \frac{1}{2}(60)3^2$

Step 4: Fill in the numbers, and solve for the unknown

$\mu = .0835$

Answer: $\mu_k = 0.0835$

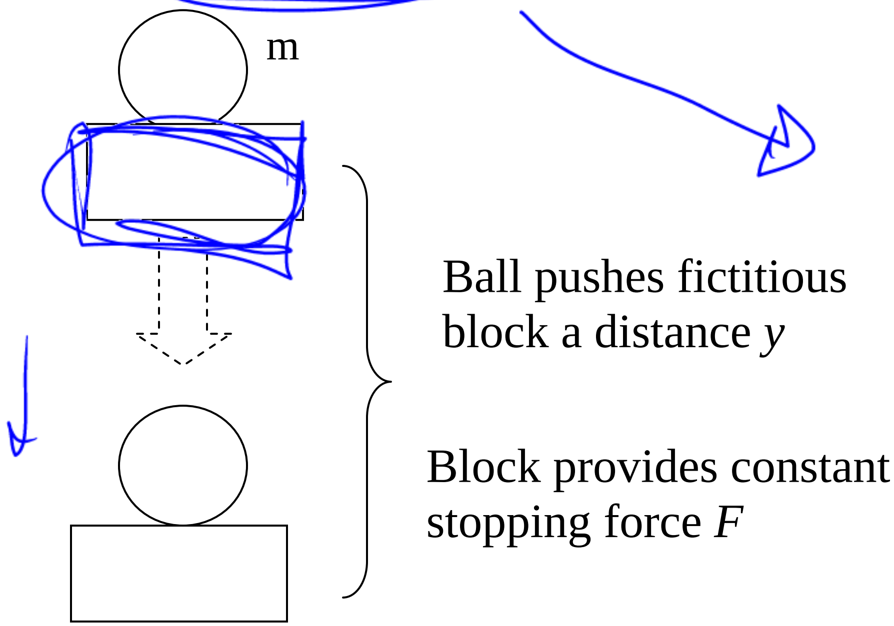
Potential Energy

Defn: Object's ability to do work that comes from its <u>position</u>.

$$PE_g = mgy$$ **P.E. of Gravity**

$= F_{gravity} \times \text{height}$

Derivation:



What must *F* be in order to avoid accumulating kinetic energy?

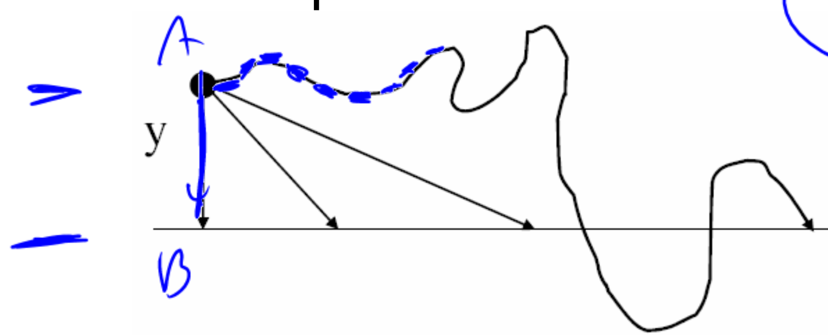
How much work does the object do as it stops?

Another way of looking at it:

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

Change in PE for the different paths?

same!



From warmup

The amount of potential energy possessed by an elevated object is equal to

a. the distance it is lifted
b. the force needed to lift it
c. the work done in lifting it
d. its acceleration due to gravity

"Conservative" vs. "nonconservative" forces:

What happens to the energy when you brake your car?
Other forms of energy?

Law of Conservation of Energy

$$KE_{before} + PE_{before} + W_{noncons} = KE_{after} + PE_{after}$$

if you have this

do not include here

Worked Problem

You throw a ball straight up with an initial velocity of 11 m/s. How high does it go?

Method 1: kinematics

Method 2: energy

Answer: 6.17 m

Question: How long does it take?

→ Can only be done with kinematics

Demo: Duckpin ball pendulum

Video: Triple Track

Video: Pole Vaulter

Q: How high can pole jumpers jump?

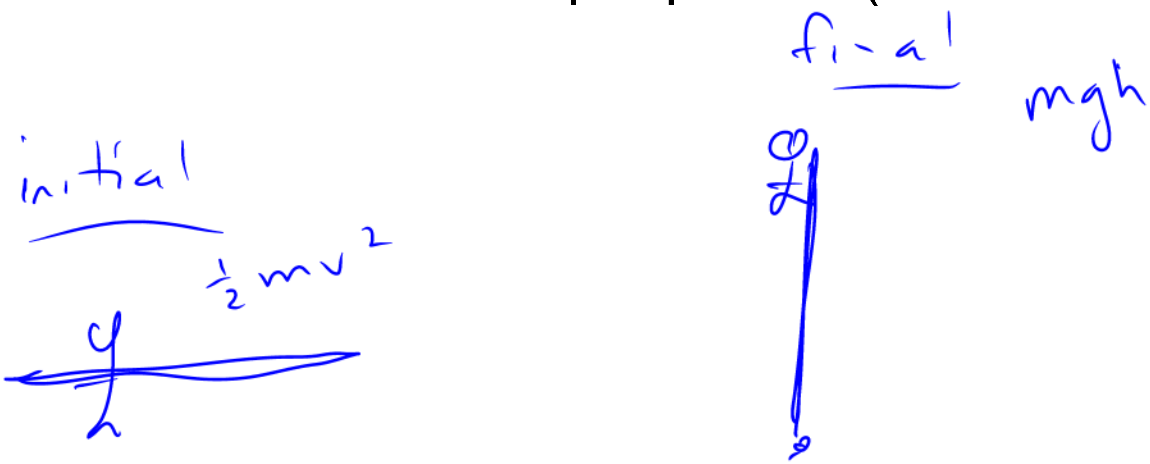
(Simple Analysis)

First: how fast can people run (short distances)?

$PE = mgy$

$= mgh$

$\sim 11\ m/s$



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

$\frac{1}{2}mv^2 = mgh$

$h = \frac{\frac{1}{2}v^2}{g} = \frac{\frac{1}{2}(11)^2}{9.8} = 6.17\ m$

Compare: Pole vault world record: 6.14 m

Review: Conservation of Energy

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

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

"Law of conservation of energy"

<u>Statement one</u>:

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

W must include work done by *all* forces

<u>Statement two</u>:

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

W includes only work by *nonconservative* forces

Both cases: *W* can be positive or negative, and can contain multiple work terms (one for each appropriate force)

Clicker quiz

You throw three balls from a cliff over the ocean with the *same initial speed.* One is thrown straight up, one straight down, and one horizontally. Ignoring air resistance, which ball has the highest speed just before it hits the ocean?

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

Demo: Racing balls

Clicker quiz: Which ball will win the race?

a. The ball that dips down
b. The ball that doesn't dip down

Demo: Cart being pulled on track

Demo problem: Dr Colton hangs a _____ kg mass from a pulley and attaches it to a ______ kg cart with a string. He lets the hanging mass fall ______ m. How fast is the cart going at the end?

Check: How long does it take to go there?