

Announcements – 24 Sep 2009

1. Exam 2 is coming up!

- a. Exam begins next week on Thurs, runs through the following Wednesday
- b. Covers Chapters 4 & 5, Homeworks 4-8

2. Clicker quiz: (do this before class) TA-led exam review session next week...when should it be? Please enter your top choice:

	<u>morning votes</u>	<u>afternoon</u>
a. Wed 6 – 7:30 pm	73	57
b. Wed 7 – 8:30 pm	67	47
c. Wed 8 – 9:30 pm		
d. Thurs 6 – 7:30 pm	86	98
e. Thurs 7 – 8:30 pm		
f. Thurs 8 – 9:30 pm		

winner!

Remember to send me suggestions about the review session if you want anything done differently.

3) If you missed points on exam 1 problem 7 because you converted to feet, please email me (if you haven't already done so).

Which part of today's assignment was particularly hard or confusing?

There were way too many equations. Please help us figure out which ones are the important ones and why.

the 5 million equations!

→ only 4!

Too many equations, and how they all interconnect. Yikes.

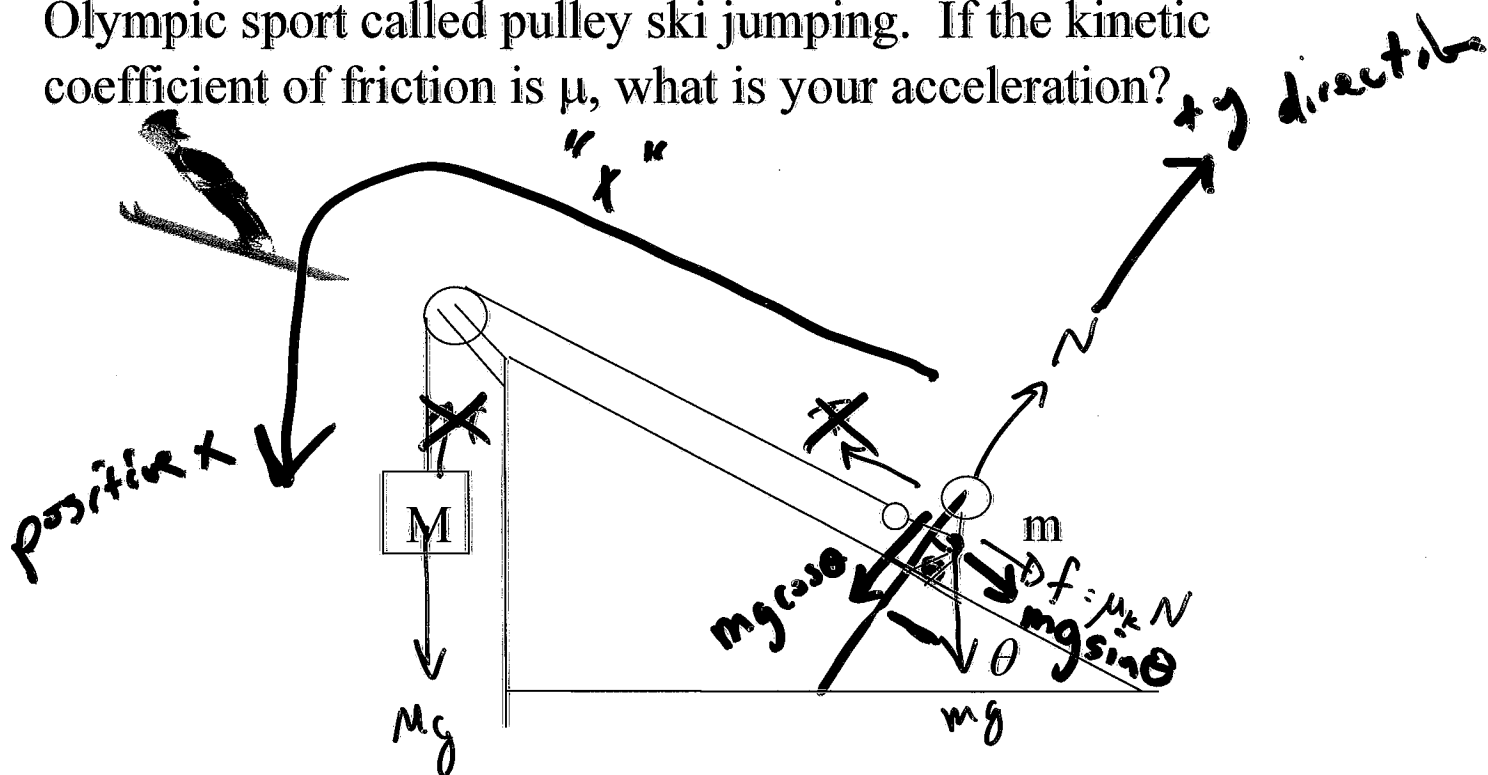
Conservative and nonconservative forces.

General comments:

I've heard that some other physics professors try to teach specifically towards "MCAT physics." What would you say to this?

lets play ping pong

Worked Problem (from last time): You invent a new Olympic sport called pulley ski jumping. If the kinetic coefficient of friction is μ , what is your acceleration?



"x" direction

$$\Sigma F_{x_{\text{group}}} = m_{\text{group}} a$$

$$+ \underline{Mg} - \underline{\mu N} - \underline{mg \sin \theta} = \underline{(M+m)a}$$

"y" direction

$$\Sigma F_{\text{skier}} = m_{\text{skier}} a_y$$

$$\underline{N} - \underline{mg \cos \theta} = 0$$

$$N = mg \cos \theta$$

$$a = \frac{Mg - \mu(mg \cos \theta) - mg \sin \theta}{M+m}$$

$$a = \left(\frac{M}{M+m} \right) g - \left(\frac{\mu mg \cos \theta + mg \sin \theta}{M+m} \right)$$

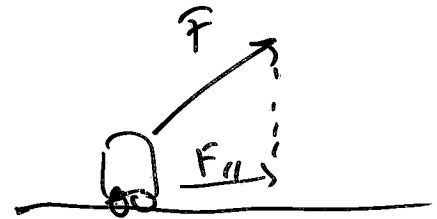
Could you figure this out: How far does the jumper travel?

New topic: Work

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:

$$W = F_{\parallel} \Delta x$$

$$W = \vec{F} \cdot \vec{\Delta x}$$

(not a vector!)

The work done **by a force** on an object is the component of the force along the direction of motion (“ F_{\parallel} ”) times the magnitude of the object’s displacement.

Disclaimer: only true if the force is constant, otherwise you need to use the average force. Or, in extreme cases, calculus.

only 51% correct!
From warmup: What if cart is carried instead of pushed? *in x-direction*
force in y-direction } no work

SI Units: $1 \text{ N} \times 1 \text{ meter} = 1 \text{ Joule}$

Recall: $1 \text{ N} = 1 \text{ kg m/s}^2$... units start getting pretty complicated

Positive vs. Negative

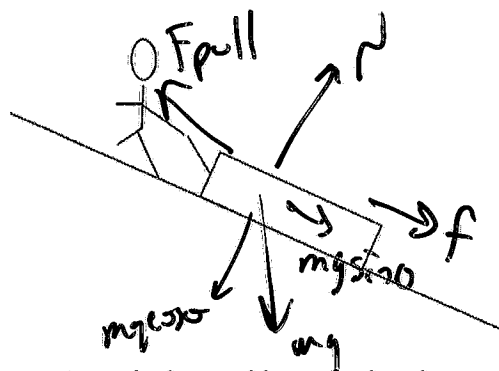
Positive if force is in line with motion → adds energy to object

Negative if force is opposite the motion → removes energy

Zero if force is perpendicular to the path → energy unchanged

Force at some angle? Use parallel component

$$W = F_{\parallel} \cdot \Delta x$$



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

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

What is energy?

Wikipedia: “The ability to do work...”

→ exert a force over a distance

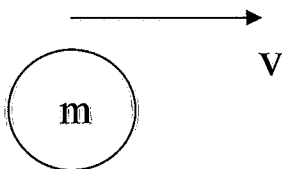
Kinetic energy

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

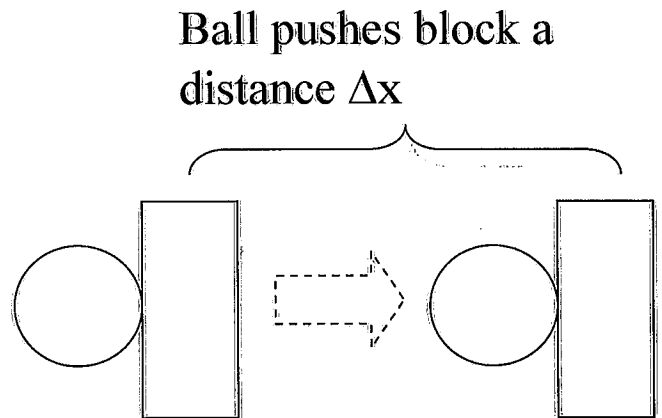
$$KE = \frac{1}{2} m v^2$$



Derivation:



Ball in motion,
sticks to block



Block provides constant
stopping force F

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 it takes !

Law of Conservation of Energy

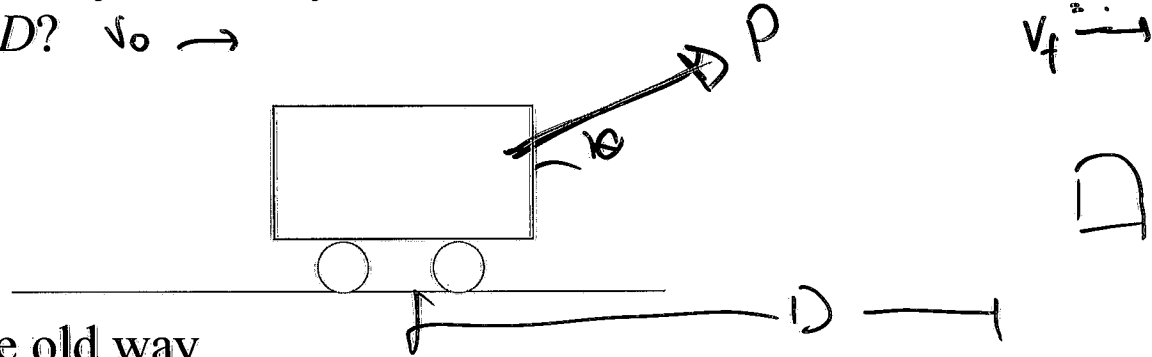
$$E_{\text{before}} + W = E_{\text{after}}$$

★ blueprint

aka "Work-Energy theorem"

Worked problem: A boy pulls his toy ^{wagon} 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 ? $v_0 \rightarrow$



Method 1: The old way

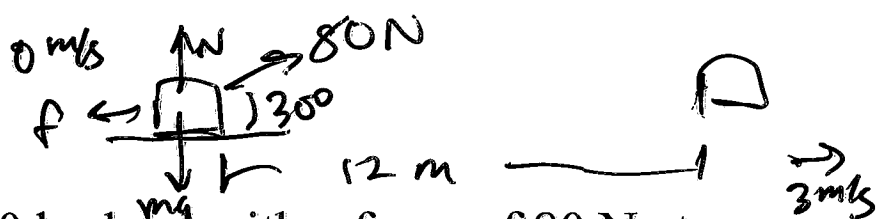
- Use N2 to figure out acceleration
- Use kinematics equations to figure out final speed, time, or whatever is wanted.

Method 2. Conservation of energy

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

$$\frac{1}{2}mv_0^2 + \overbrace{(P \cos \theta) D}^{F_{\text{net}} \cdot x} = \frac{1}{2}mv_f^2$$

$$v_f = \sqrt{\frac{2}{m} \left[\frac{1}{2}mv_0^2 + P \cos \theta D \right]}$$



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.

Question: Was the net work done on the wagon positive, negative, or zero?

Clicker quiz: What work did *you* do on the wagon? (From *your* force) $W = F_{||} \Delta x$

a. 0-100 J

d. 300-400

b. 100-200

e. 400+

c. 200-300

$$W = (80 \cos 30^\circ)(12) = 831 \text{ J}$$

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

a. 0-100 J

d. 300-400

b. 100-200

e. 400+

c. 200-300

$$\cancel{W_{\text{pull}}} + W_{\text{net}} = E_{\text{alt}}$$

$$W_{\text{net}} = \frac{1}{2} m v_f^2$$

$$= \frac{1}{2} (60) (3^2) = 270 \text{ J}$$

Question: What was the work done by friction on the wagon?

$$831 - 270 = 561 \text{ J negative}$$

Answer: -561 J

Gravitational potential energy

PE_{gravity} keeps track of the Work done against gravity

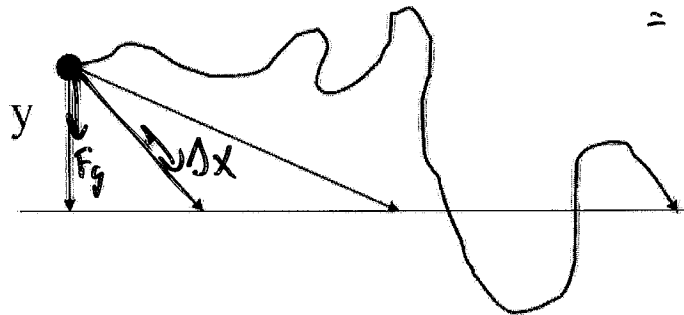
Formula:

$$PE_g = mgy$$



Derivation: work = force \times distance

Change in PE for the different paths?



$$\begin{aligned} &F_{\parallel} \cdot \Delta x \\ &= F \cdot (\Delta x)_{\parallel} \\ &= \text{same} \end{aligned}$$

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. it's acceleration due to gravity

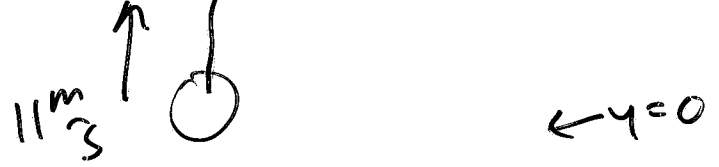
only 43% correct

“Conservative” vs. “nonconservative” forces:

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

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

$$\begin{aligned}
 E_{\text{bef}} + \cancel{W_{\text{net}}} &= E_{\text{aft}} \\
 K E_{\text{bef}} &= P E_{\text{aft}} \\
 \frac{1}{2} m v_0^2 &= m g h \quad h = \frac{1}{2} \frac{v_0^2}{g} = \frac{1}{2} \frac{11^2}{9.8} = \boxed{6.17 \text{ m}}
 \end{aligned}$$

Question: How long does it take?

→ Can only be done with kinematics

Demo: Duckpin ball pendulum

Video: Triple Track

Video: Pole Vaulter

Simple Analysis: How high can pole jumpers jump?

Top velocities: ~11 m/s for short distances

Compare: Pole vault world record: 6.14 m

Answer: 6.17 m

Conservation of Energy, revisited

“Energy cannot be created or destroyed, only changed from one form into another...” [*mostly true*]

$$(E = mc^2)$$

$$E_{before} + W_{net} = E_{after}$$

“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 includes only work by *nonconservative* forces

those with no PE. expressions

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

From warmup: A car coasting from rest down two hills, one steeper than the other, will arrive at the bottom of each hill with the same speed, as long as the two hills have the same vertical height (neglecting friction & air resistance). Ralph wondered how this could be possible, since as we learned in class the acceleration of the car down the steep hill will be greater than down the other hill. What should you tell him?

Answer from the class:

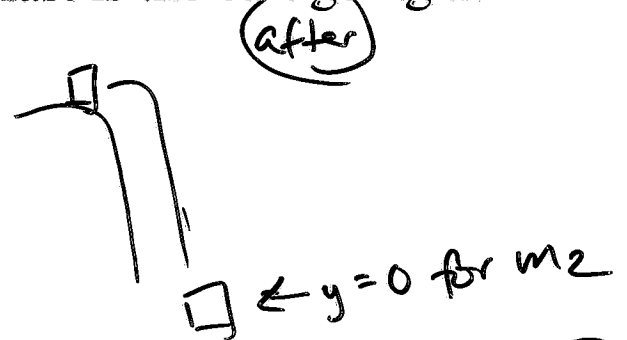
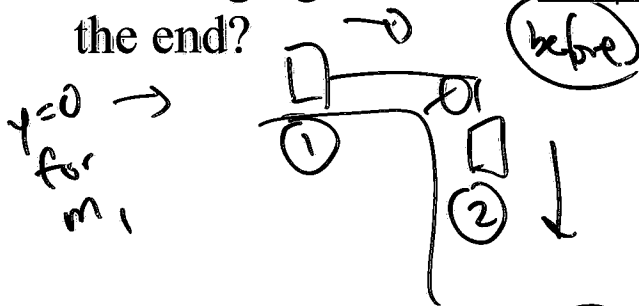
420-----

It would take less time to get to the bottom of the [steeper] hill and therefore the final velocity would be the same.

Demo: Cart being pulled on track

0.5

Demo problem: Dr Colton hangs a ~~10~~ kg mass from a pulley and attaches it to a 1.5 kg cart with a string. He lets the hanging mass fall 1 m. How fast is the cart going at the end?



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

$$(\cancel{PE_1} + \cancel{KE_1}) + (\cancel{PE_2} + \cancel{KE_2}) + W_{\text{net}} = (\cancel{PE_1} + \cancel{KE_1}) + (\cancel{PE_2} + \cancel{KE_2})$$

_{initial} _{final}

$$m_2 g y = \frac{1}{2} m_1 v_f^2 + \frac{1}{2} m_2 v_f^2$$

$$m_2 g y = \left(\frac{1}{2} m_1 + \frac{1}{2} m_2 \right) v_f^2$$

Check: How long does it take to go there?

Solve for v_f