Announcements – 30 Sep 2014

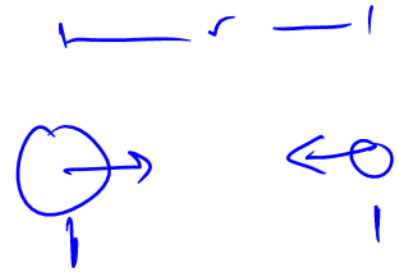
1. Prayer

2. Exam 1!!
   a. Thursday Oct 2 – Tuesday Oct 7 (2 pm) in the Testing Center, late fee after Oct 6, 2 pm
   b. Covers through first part of today's lecture ~~(unless we don't quite finish, in which case it covers through start of Tuesday's lecture)~~
   c. Covers through HW 9 (due Wed, Oct 1)
   d. Exam review sessions by Jerika, both in room C295 ESC:
      a. Wed Oct 1, 7 - 8:30 pm
      b. Thurs Oct 2, 6 - 7:30 pm
   e. I will give you conversion factors (but not basic metric system)
   f. Bring a note card! (I won't give you any equations) 3"x5" handwritten only
   g. Bring a calculator!
   h. 28-30 problems
   i. Probably will take ~2 hours average. Some students <1 hour, other students >3 hours

"Which of the problems from last night's HW assignment would you most like me to discuss in class today?"

Newton's Law of Gravity

All masses attract all other masses!



$$F_G = G\frac{mM}{r^2}$$

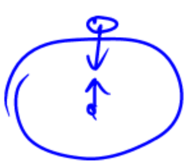
r measured from centers

(sometimes written with negative sign)

Proportionality constant: $G = 6.674 \times 10^{-11}\ \mathrm{N{\cdot}m^2/kg^2}$

Near the surface of the earth:

$R_{Earth} = 6.371\times10^{6}$ m
$M_{Earth} = 5.974 \times 10^{24}$ kg



$$F = G\frac{m M_{Earth}}{R_{Earth}^2} = mg$$

$$\frac{(6.67\cdot10^{-11})(5.97\cdot10^{24})}{(6.37\cdot10^{6})^2}$$

Clicker quiz

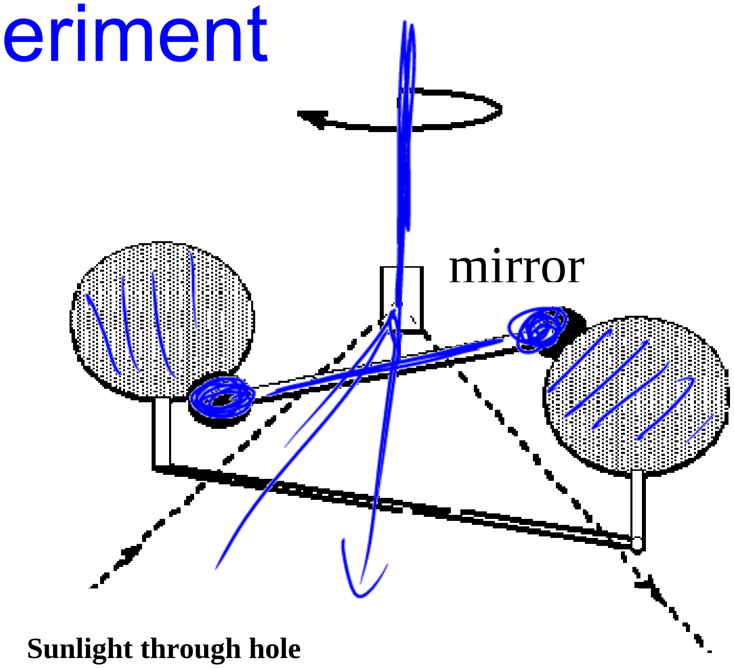
You are on planet Xarthon, which has a mass of 2× that of the earth and a radius 2× as big. If you throw a ball at the surface, and you will find that $g_{Xarthon}$ is ____ g_{earth}

a. 2× larger than
b. 4× larger than
c. 2× smaller than
d. 4× smaller than
e. the same as

$$F_G = \frac{GmM}{R^2} = mg$$

$$\frac{2M}{(2R)^2} = \frac{1}{2}\frac{M}{R^2}$$

Cavendish Experiment



1783: first measurement of forces between “regular” masses, by Cavendish.

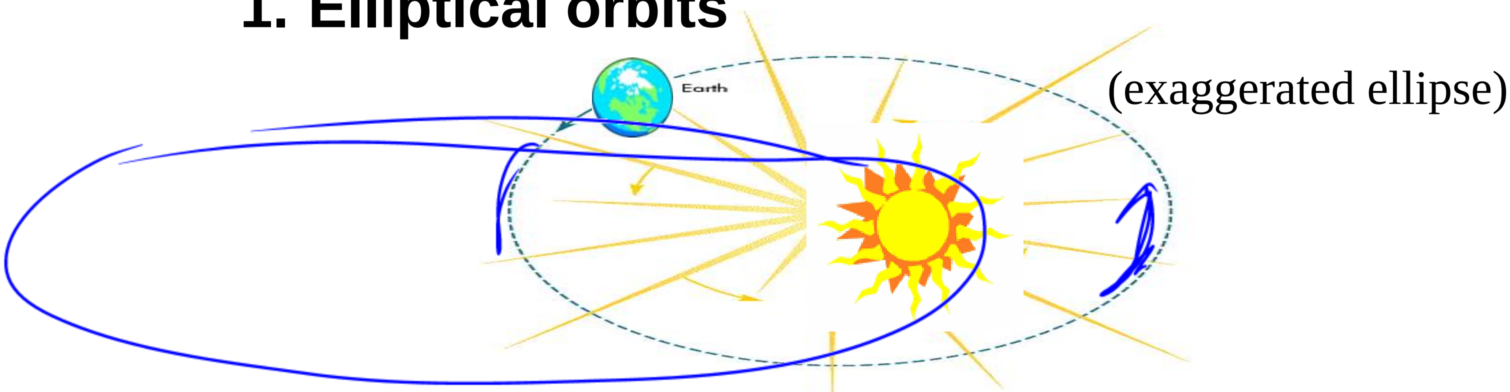
“Weighing the world” vs. determining *G*

→ Most accurate such measurement for 102 years!
(only 1% off of today’s value)

How did Newton know it was **inverse square**?

Kepler's laws (about 1600) came from observations of the planets in our solar system:

1. Elliptical orbits



2. Equal areas in equal times: fastest close to Sun

3. $T^2 \sim r^3$

(T = "orbital period", for earth around sun = 365.25 days)

All three can be exactly predicted using Newton's Second Law together with Newton's Law of Gravity! (Done in Phys 321)

Worked Problem

How long is Jupiter's year? ($r_{Jupiter} \approx 5.2\ r_{Earth}$)
(hint: $T^2 \sim r^3$)

$$\frac{T_e^2}{T_J^2} = \frac{\cancel{C}\, r_e^3}{\cancel{C}\, r_J^3}$$

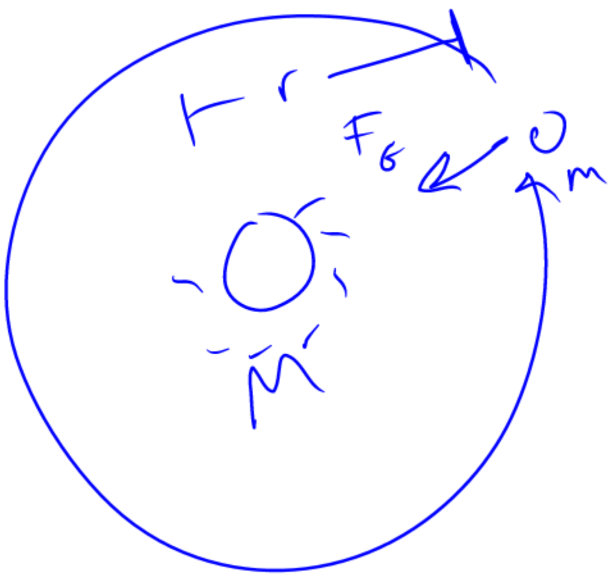
$$T_J = \sqrt{\frac{T_e^2\, r_J^3}{r_e^3}} = T_e \sqrt{\frac{r_J^3}{r_e^3}} = (1\ \text{yr})\left(\sqrt{5.2^3}\right)$$

$$= \boxed{11.86\ \text{yr}}$$

Answer: 11.86 years

Worked Problem

Figure out what the proportionality constant is in Kepler's Third Law, $T^2 \sim r^3$, in terms of *G* and the mass of the sun. Assume a circular planetary orbit.



$$\Sigma F = m a_c \qquad v = \frac{2\pi r}{T}$$

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

$$\frac{GM}{r} = \frac{4\pi^2 r^2}{T^2}$$

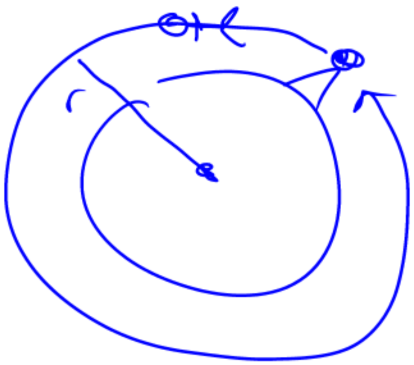
$$T^2 = \left(\frac{4\pi^2}{GM_{sun}}\right) r^3$$

Answer: $4\pi^2/(GM)$

Orbital Velocity

On the moon (no air friction, mass M) someone really *could* get in a circular orbit by being fired horizontally off the highest mountain (radius r).

How fast would you have to shoot that person?



$$\Sigma F = m a_c$$

$$\frac{G M_{moon} m_{person}}{r^2} = m_{person} \frac{v^2}{r}$$

$$v = \sqrt{\frac{G M_{moon}}{r_{orbit}}}$$

How long would it take him to go around once?

"orbital period"

$$v = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{\sqrt{\frac{G M_{moon}}{r_{orbit}}}}$$

Answers: v=sqrt(GM/r), 2πr/v

Satellites orbiting the Earth

Circular orbits

For each *v*, only one *r* will work

For each *r*, only one *v* will work!

Clicker quiz: A satellite in a higher orbit will be going ________ than a satellite in a lower orbit.

a. faster

b. slower

NASA satellite tracker

http://science.nasa.gov/realtime/jtrack/3d/JTrack3D.html/

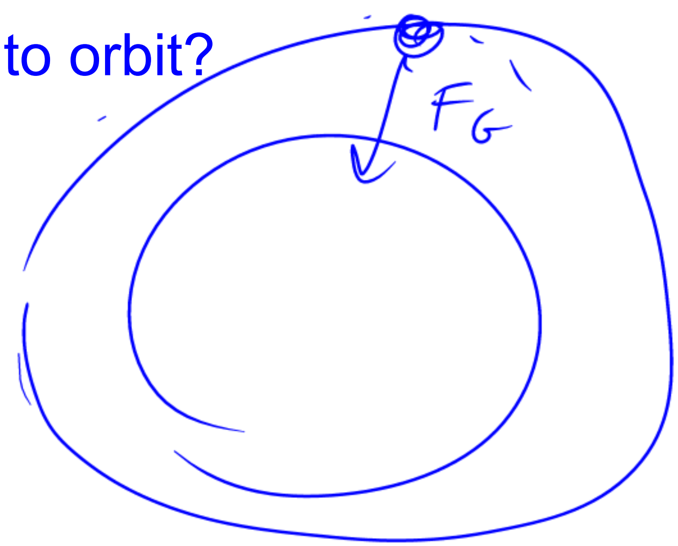
(may need to change security settings in Java control panel)

International space station, 340.5 km above surface of Earth (R_e = 6,371 km)	7.707 km/s
Geostationary orbit, 35,786 km above surface	3.075 km/s
Moon, r = 381,715 km	1.022 km/s

Worked Problem: How long does it take ISS to orbit?

$\Sigma F = m a_c$

$G\frac{Mm}{r^2} = m\frac{v^2}{r}$



Answer: 91.2 min

$v = \sqrt{\frac{GM}{r}}$

Clicker quiz

Satellites in higher orbits are travelling <u>slower</u>, so to “shoot” a satellite from the surface of the earth into a high orbit (i.e. with a cannon), you would provide it with ________ initial kinetic energy than for a satellite in a low orbit

a. more
b. less
c. same

Review

Centripetal Acceleration:

Causes change in direction but not change in speed

Direction: inward

Magnitude: $a_c = v^2/r$

How to use with N2: Always include on the right hand side!

How to use with Newton's Law of Gravity: Always include GmM/r^2 on the left hand side

The End of Exam 1 Material

New topic: Work and Energy

Demo: Moving a cart at constant velocity

Clicker quiz: Who did the most "work"?

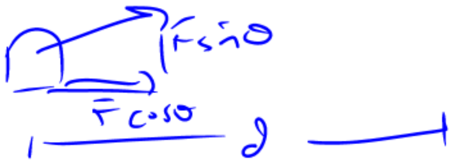
a) the one who lifted the cart
b) the one who moved the cart horizontally
c) same work done

Definition of work in physics, aka "mechanical work"

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

(not a vector!)

(but can be negative)



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

Units of work?

force × distance

N · m

= "J" joule

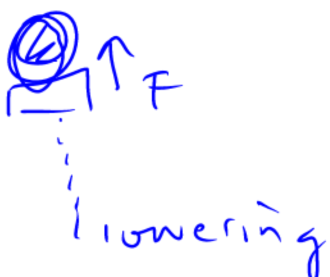
$$W = F_{//} d$$

What if **F** is in line with **d**? Then $W = F \cdot d$

What if **F** is at an angle θ away from **d**? $W = F \cos\theta \, d$

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

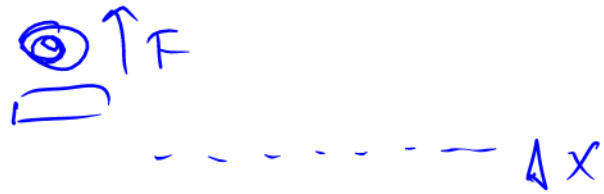
$W = - F \cdot d$



What if **F** is not constant?

use ave. F

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

$W = F_{\parallel} d = 0$

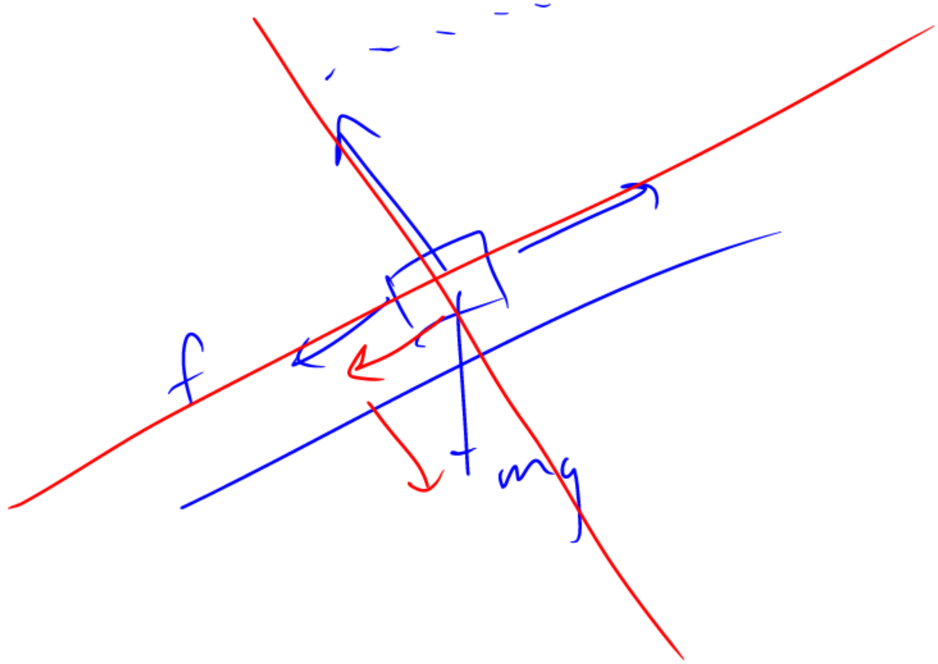
You need to carry a suitcase up a flight of stairs. In which case will you do the most mechanical work?

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

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

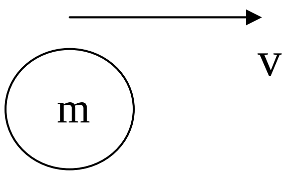


Kinetic Energy

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

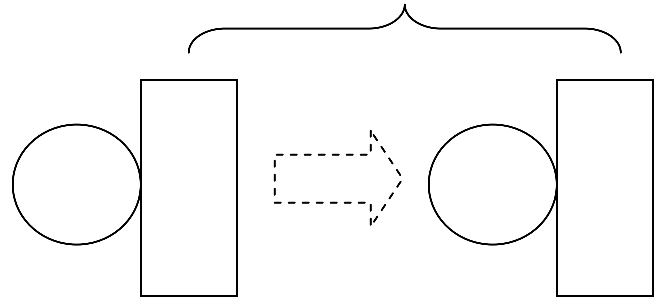
$$KE = \frac{1}{2} m v^2$$

Derivation:



Ball in motion, sticks to block

Ball pushes fictitious block a distance Δx



Block provides constant stopping force F

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.

Potential draw back: the work/energy equations have no information about ___time___!

Law of Conservation of Energy

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

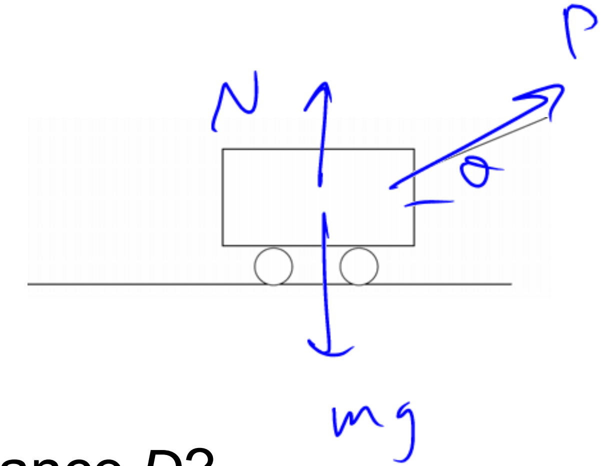
aka “Work-Energy theorem”

A new blueprint!!

Problem solving hint for conservation of energy problems:
Always draw “before” and “after” pictures. Maybe also draw a FBD for the "between" section if you need to think carefully about forces.

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*?

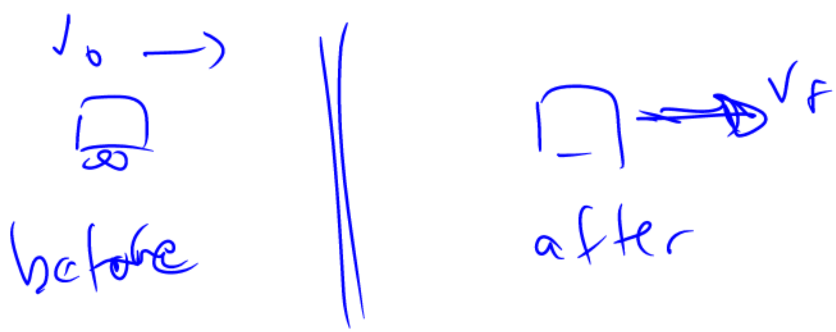
Method 1: The old way

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

$F_{\parallel} \cdot d$

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

Method 2. Conservation of energy



$\frac{1}{2}mv_0^2 + (P\cos\theta)D = \frac{1}{2}mv_f^2$

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

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

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?

$\Sigma F_y = 0$

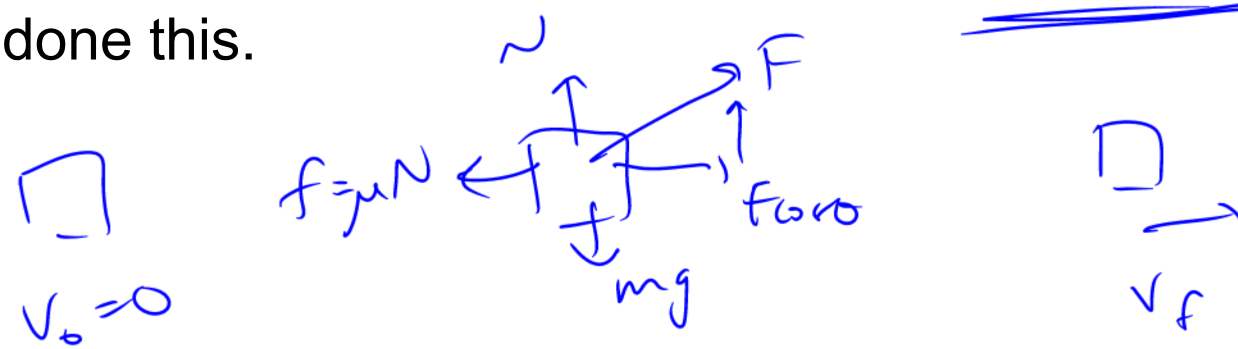
Step 1: Draw before and after pictures, and a FBD for the in-between part.

$N - mg + F\sin\theta = 0$

$N = mg - F\sin\theta$

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

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

Step 2: Write down the work/energy blueprint equation

Clicker quiz: I have done this.

a. yes
b. no

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

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

$$0 + (80\cos\theta)(12\,m) - \mu(mg - 80\sin\theta)12 = \frac{1}{2}m(3^2)$$

Clicker quiz: I have done this.

a. yes
b. no

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

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

$$(80\cos 30^\circ)(12) - \mu(60\cdot 10 - 80\sin 30)(12) = \frac{1}{2}(60)(9)$$

$$F\cos\theta\cdot D - \mu N = \frac{1}{2}mv^2$$

$$N = mg - F\sin\theta$$

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

Answer: μ_k = 0.0835

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

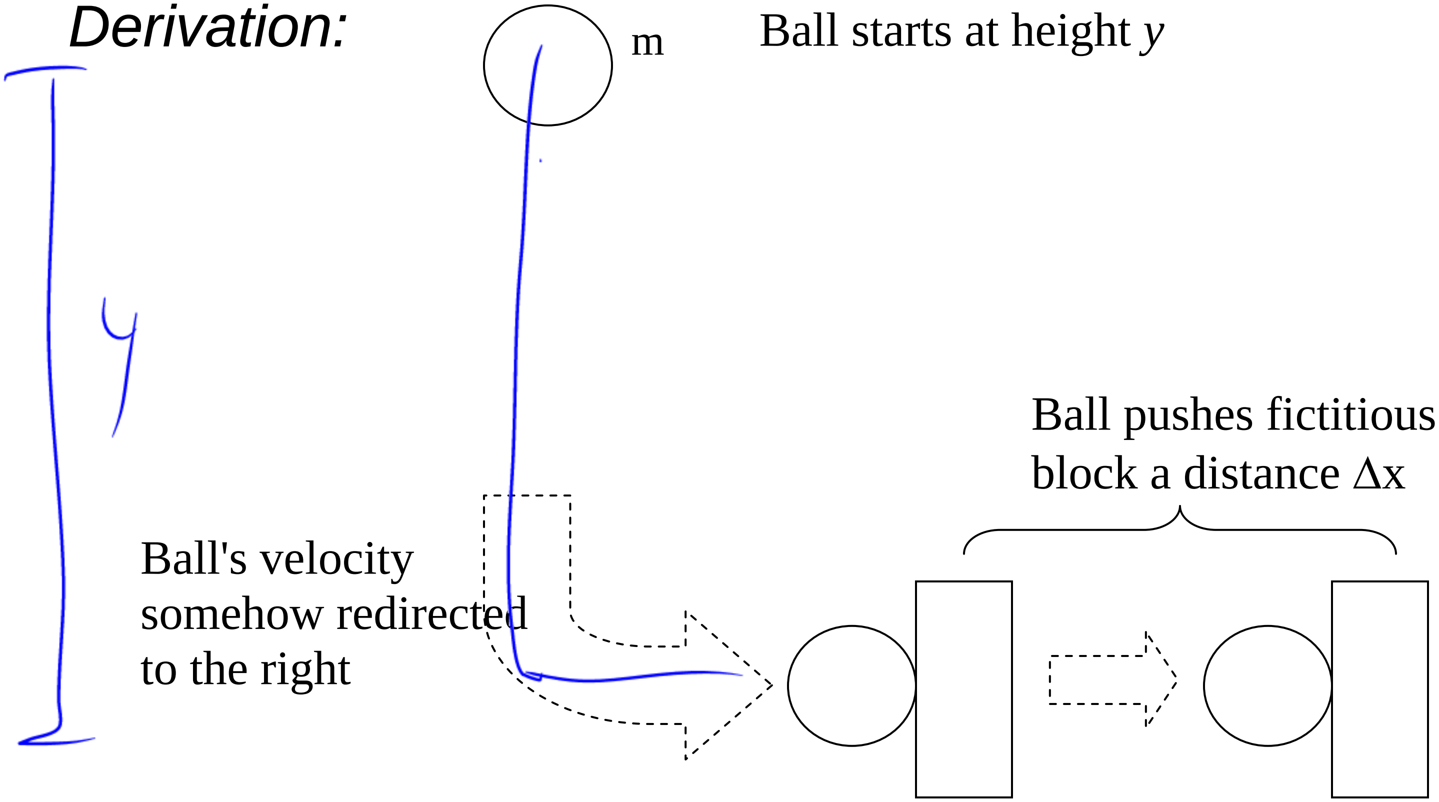
Potential Energy

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

$$PE_g = mgy$$

P.E. of Gravity

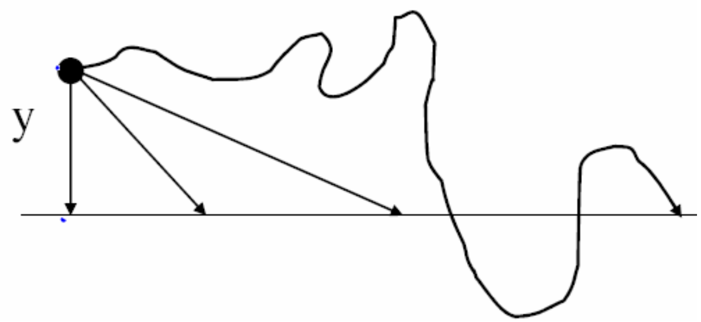
Derivation:



How much work does the ball do on the block as it stops?

Path doesn't matter

Change in PE for the different paths?



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

Like storing money in a bank…

Worked Problem

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

Method 1: kinematics (you can do if you want)

Method 2: energy

$$E_{bef} + W = E_{aft}, \quad W = 0$$

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

$$\frac{1}{2} m v^2 = m g y$$

$$y = \frac{\frac{1}{2} v^2}{g}$$

Answer: 6.17 m

Question: How long does it take?

→ Can only be done with kinematics

Video

Triple Track

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?

“Think-pair-share”

- Think about it for a bit
- Talk to your neighbor, find out if he/she thinks the same as you
- Be prepared to share your answer with the class if called on

Clicker: I am now ready to share my answer if randomly selected.

a. Yes

Note: you are allowed to "pass" if you would really not answer.

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

Clicker quiz

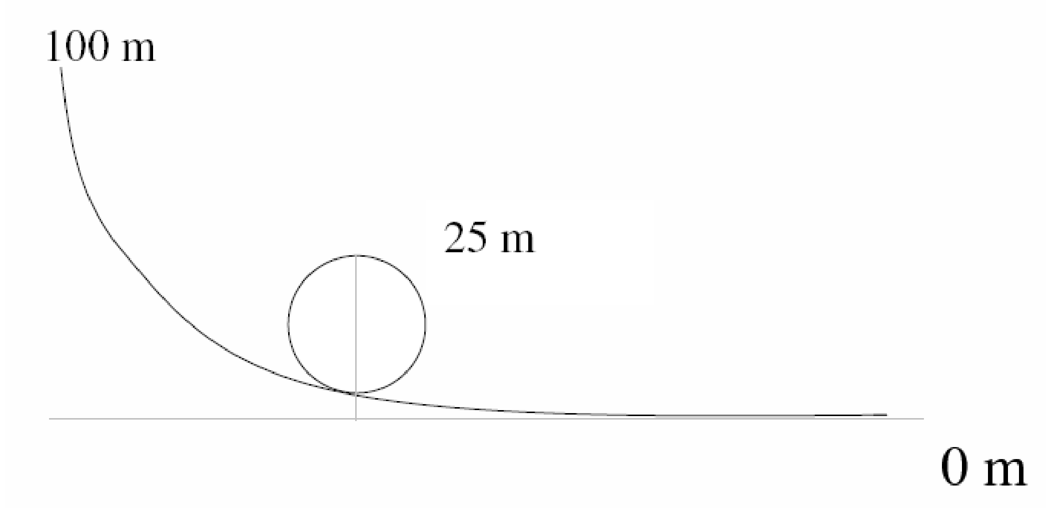
You throw three balls from a cliff over the ocean with the *same initial speed.* One is thrown straight up, one straight down, and one horizontally. Ignoring air resistance, which ball has the highest speed just before it hits the ocean?

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

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



Could you do this with N2??

“Conservative” vs. “nonconservative” forces:

Gravity = conservative

Demo: Duckpin ball pendulum

Friction = nonconservative.

What happens to the energy when you brake your car?

Other forms of energy?

Law of Conservation of Energy

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