# Announcements – 2 Oct 2014

1. Prayer
2. Exam 1 starts today!
    a. Thursday Oct 2 – Tuesday Oct 7 (2 pm) in the Testing Center, late fee after Oct 6, 2 pm
    b. ~~Covers through 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:
        1. Wed Oct 1, 7 - 8:30 pm
        2. Thurs Oct 2, 6 - 7:30 pm
    e. I will give you conversion factors (but not basic metric system)
    f. Bring a handwritten 3"x5" note card (I won't give you any equations)
    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?"

# **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

c. they tie

# Clicker quiz

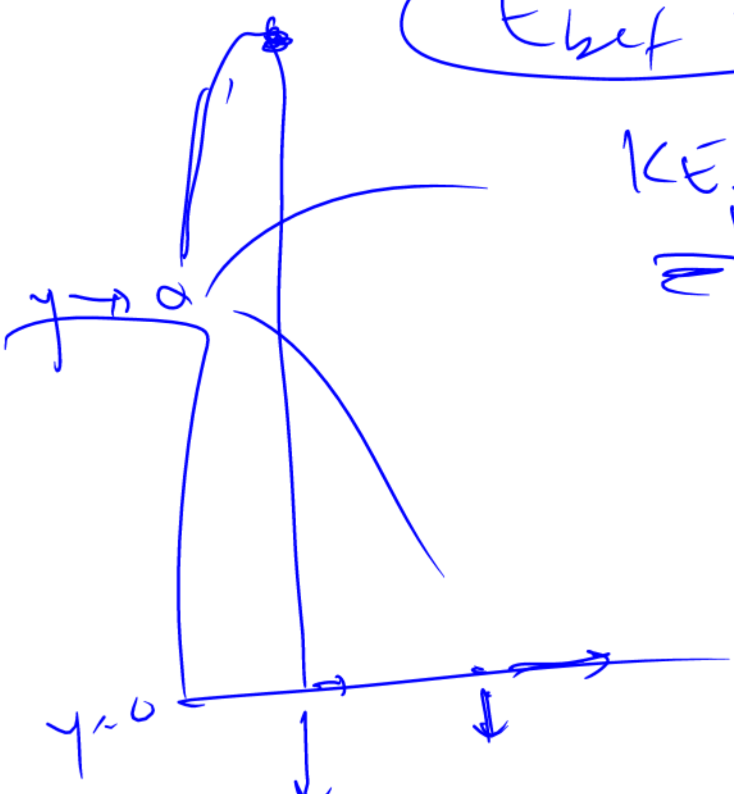
You throw three balls from a cliff over the ocean with the same initial speed. One is thrown straight up, one straight down, and one horizontally. Ignoring air resistance, which ball has the highest speed just before it hits the ocean?

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

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

$KE_i + PE_i = KE_f$

$mgy$



# Clicker quiz

Gravitational *PE* = *mgy*. Where should you measure y from?

a. the highest point in the problem
b. the lowest point in the problem
c. the average point in the problem
d. it doesn't matter

1 kg  $g = 10\ m/s^2$

i.e. where do you call $y = 0$?

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

$PE_i + KE_i = KE_f$

$mgy + \frac{1}{2}mv_0^2 = \frac{1}{2}mv_f^2 + mgy_f$

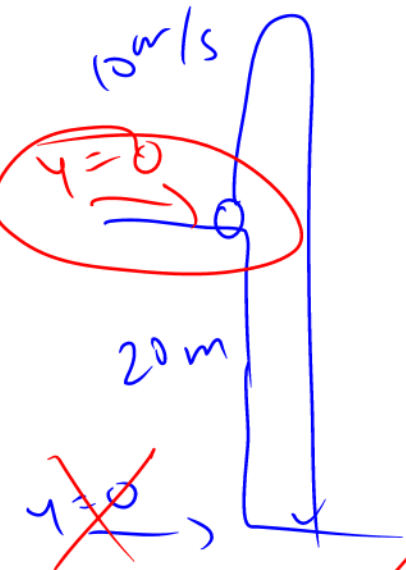
$(1)(10)(20) + \frac{1}{2}(1)(10)^2 = \frac{1}{2}(1)v_f^2$

$200 + 50 = \frac{1}{2}v_f^2$

$250 = \frac{1}{2}v_f^2$

$500 = v_f^2$

$v_f = \sqrt{500}\ m/s$




$\frac{1}{2}(1)(10)^2 = \frac{1}{2}(1)v_f^2 + (1)(10)(-20)$

$50 = \frac{1}{2}v_f^2 - 200$

$250 = \frac{1}{2}v_f^2$

# 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

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

$PE_i = PE_f + KE_f$

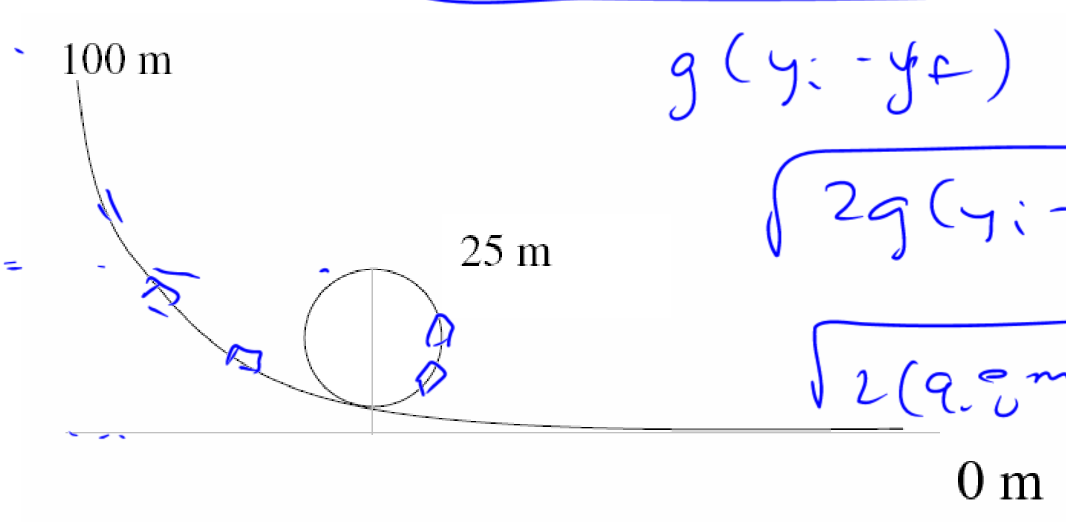
$mgy_i = mgy_f + \frac{1}{2}mv_f^2$

$g(y_i - y_f) = \frac{1}{2}v_f^2$

$\sqrt{2g(y_i - y_f)} = v_f$

$\sqrt{2(9.8\ m/s^2)(100\ m - 25\ m)}$

$= 38\ m/s$




**Could you do this with N2??**

# "Conservative" vs. "nonconservative" forces:

Gravity = conservative

**Demo**: Bowling ball pendulum

Friction = nonconservative.

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

# Review: Conservation of Energy

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

"Law of conservation of energy"

First view:

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

*W* must include work done by *all* forces

Second view:

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

*W* includes only work by *nonconservative* forces

# Dr Colton's Guide:
# How to solve Conservation of Energy problems

1. Draw "before" and "after" pictures, and if needed an "in between" FBD.

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

*Blueprint equation*

2. Write down the blueprint equation, and fill in to get a "real equation":
   - Include all PE and KE terms for each "before" object, on the left hand side
   - Include all PE and KE terms for each "after" object, on the right hand side
   - Include work on the left hand side for each non-conservative force. If needed, use the FBD and N2 to figure out the force.

     → One work term for each force that doesn't have a PE

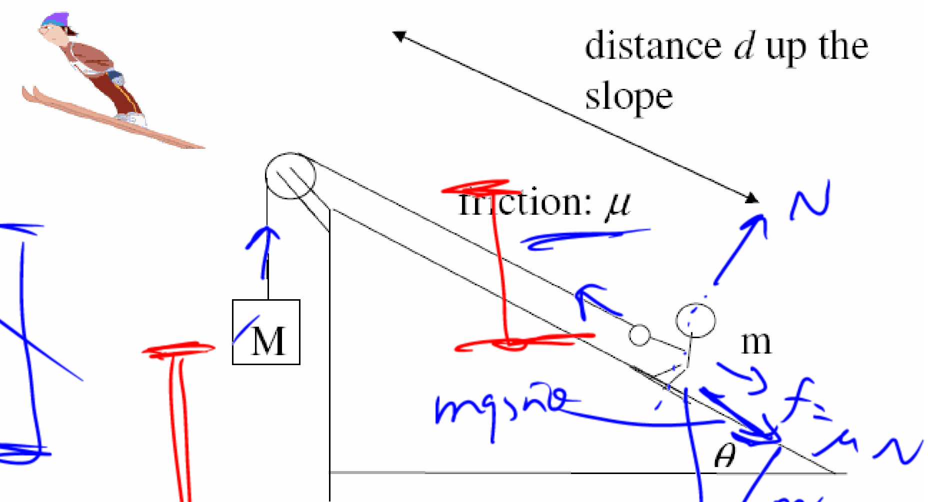
$$KE = \tfrac{1}{2} mv^2$$

$$PE_{grav} = mgy$$

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

3. Plug what you know into the "real equation", and look at what results!

**Worked Problem:** In terms of M, m, $\mu$, d, and $\theta$, what is his takeoff speed?




Pictures:

Blueprint:

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

Fill in:

$PE_{im} + PE_{ib} + KE_{im} + KE_{ib} - f(d) = PE_{fm} + PE_{fb} + KE_{fm} + KE_{fb}$

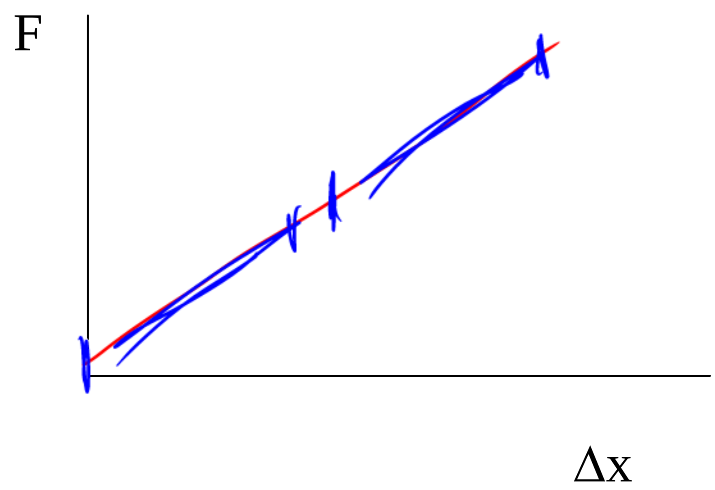
Plug in given quantities:

$-\mu mg\cos\theta\, d = mg(d\sin\theta) - Mgd + \frac{1}{2}mv^2 + \frac{1}{2}Mv^2$

Solve for what you want:

$$v = \sqrt{\frac{Mgd - mgd\sin\theta - \mu mg\cos\theta\, d}{\frac{1}{2}m + \frac{1}{2}M}}$$

# Springs




Hooke's Law: Proportionality factor $k$ = "spring constant"

$$F_{spring} = kx$$

(often with negative sign: force acts opposite displacement)

*Caution: x* must be measured from equilibrium position (unstretched)

# Springs are conservative

$$PE_{spring} = ½\, kx^2$$

*Derivation*: force is varying → must use *average* force

$$W = F_{ave}x \qquad \text{Work done to compress or stretch}$$

$$= \left(\frac{1}{2}F_{final}\right)x \qquad \text{Force is linearly varying}$$

$$= \left(\frac{1}{2}kx\right)x$$

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

# From warmup

You compress a spring 10 cm from its equilibrium position. Then you compress it another 10 cm. In which step did you do more work?

a. The first 10 cm
b. The second 10 cm
c. Both cases involve the same amount of work

Hint: two ways to think about this

1. Think of change in spring potential energy
2. Think of average force during the compression

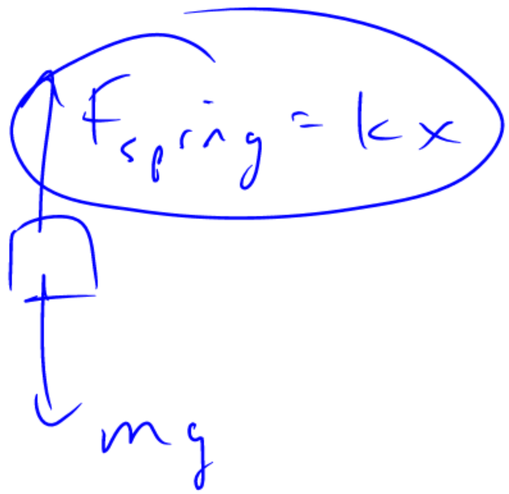
# Experimental Problem

Determine the spring constant of a hanging spring.

500 g → 28 cm stretch

Method 1: Use forces and N2 (need nonmoving spring)

FBD:




$$\Sigma F = ma = 0$$

$$kx - mg = 0$$

$$k = \frac{mg}{x} = \frac{(.5\,\text{kg})(9.8\,\text{m/s}^2)}{.28\,\text{m}} = 17.5\,\text{N/m}$$

# Experimental Problem

Determine the spring constant of the spring inside the "vertical cannon cart"

Method 2: Spring PE converted to gravity PE

40 cm height

80 g

7 cm compression

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

$$PE_s = PE_g$$

$$\frac{1}{2} k x^2 = mgy$$

$$k = \frac{2mgy}{x^2}$$

$$= \frac{2(.080\,\text{kg})(9.8\,\text{m/s}^2)(.40\,\text{m})}{(.07\,\text{m})^2}$$

$$= 128\ \text{N/m}$$

# Worked Problem

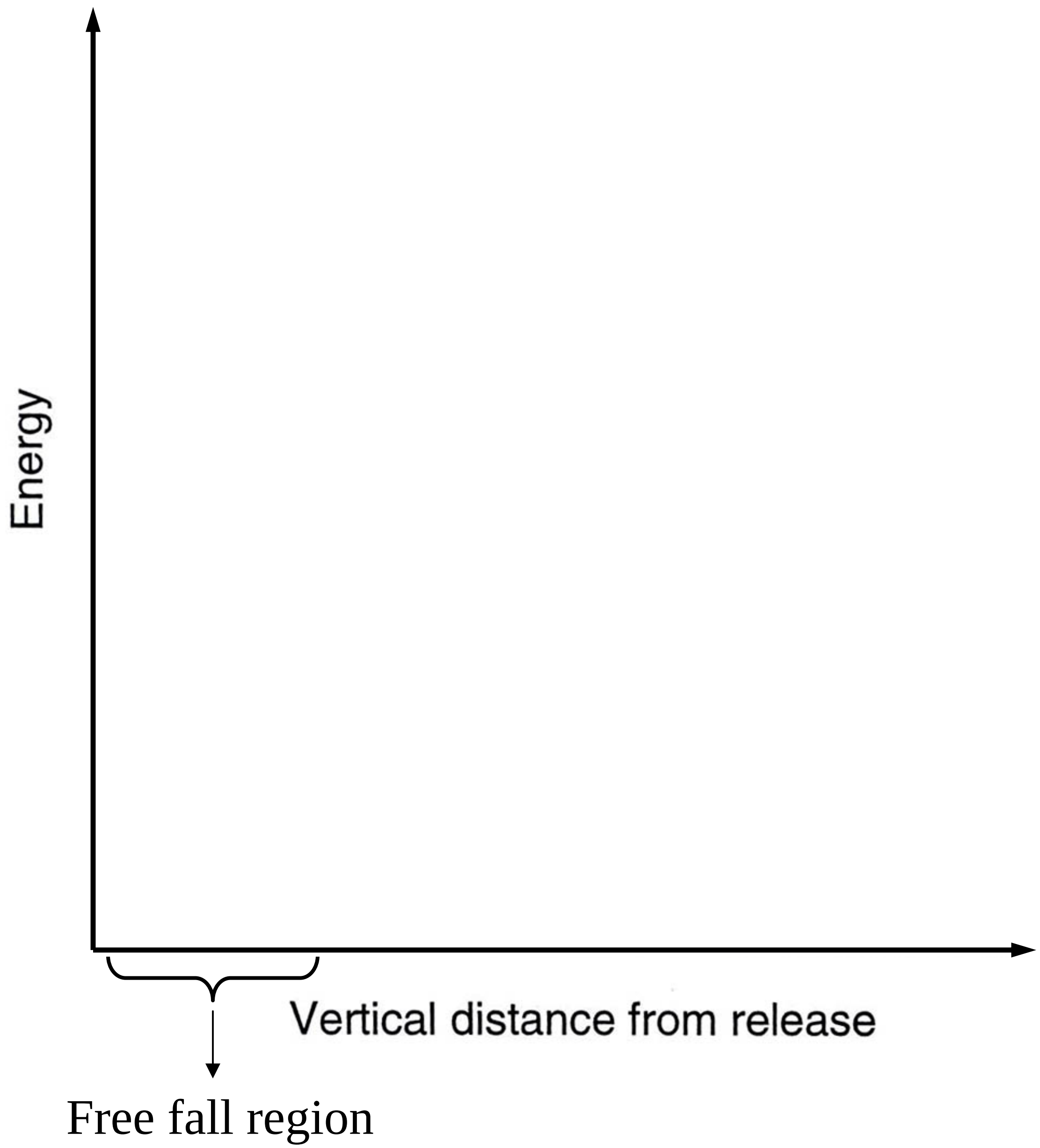
Fred goes ice-blocking on the grass. He is 50 kg (including ice). Starting from rest he rides 40 m down a hill which has a 20° slope. $\mu_k = 0.2$ between the ice and grass.

(a) What is his speed at the bottom?

(b) How far will will he go horizontally after he reaches the bottom?

Answers: 10.99 m/s, 30.82 m

# Bungee jumping: types of energy



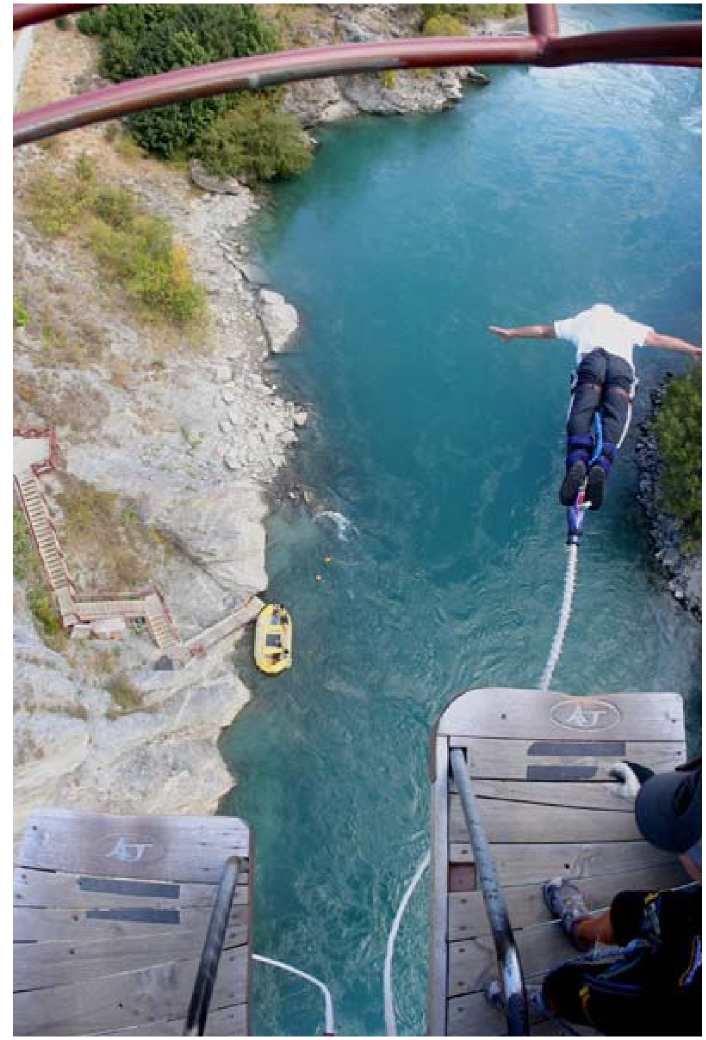
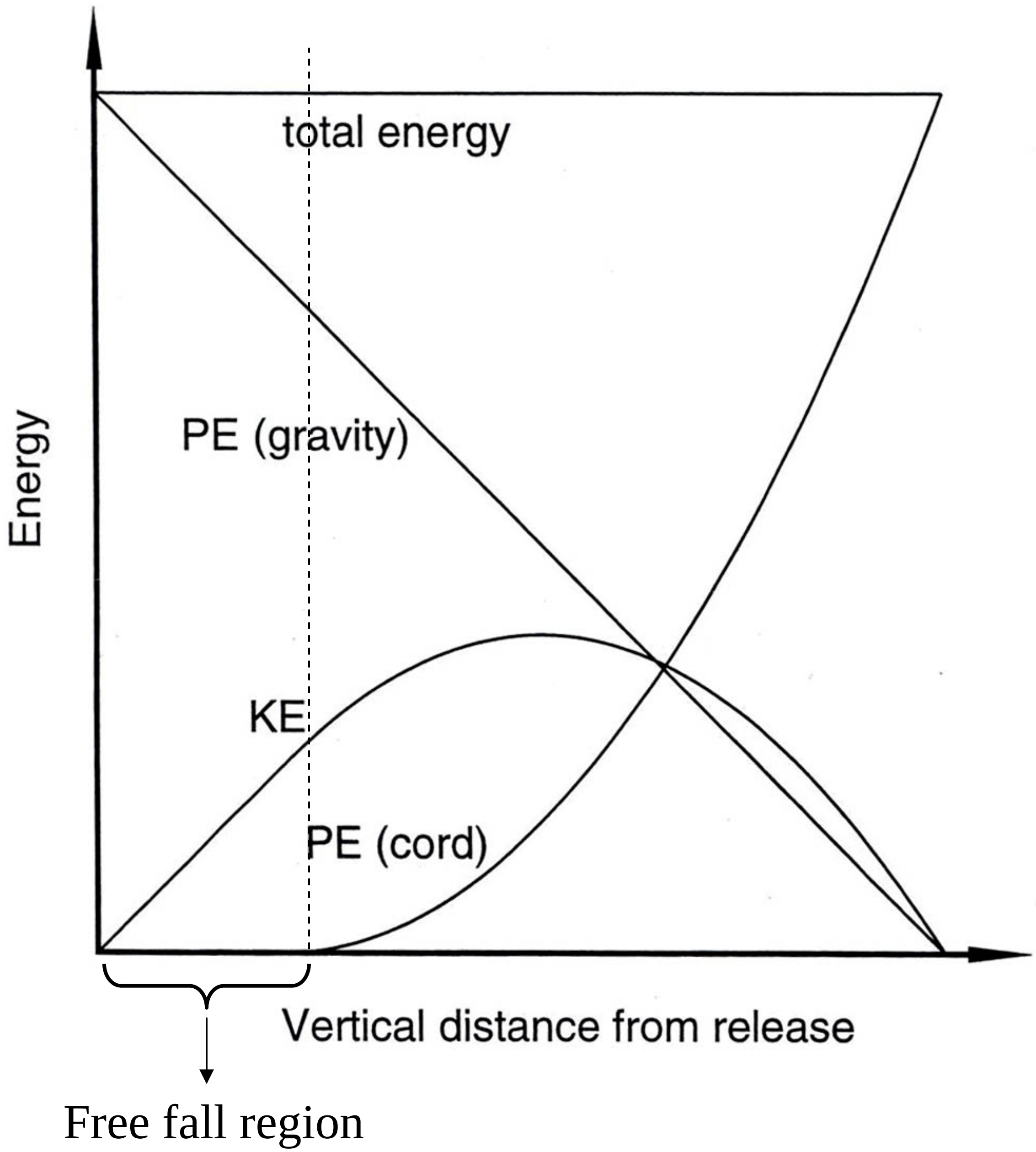



Image credit: Wikipedia


total energy
PE (gravity)
KE
PE (cord)
Energy
Vertical distance from release
Free fall region

# Satellites, again

Why are satellites in higher orbits travelling slower than satellites in lower orbits?

# Gravitational PE

Need new $\mathbf{PE_{gravity}}$

**PE = mgy** won't work…
Force isn't "mg" any more! It's changing!!

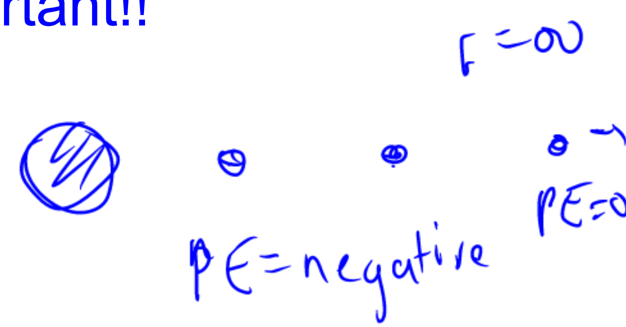
$PE = F_{ave}d$

$F = \frac{GmM}{r^2}$

Use calculus to calculate average force …

$$PE_G = -\frac{GMm}{r}$$

Here the negative sign is critically important!!
(not a vector direction)

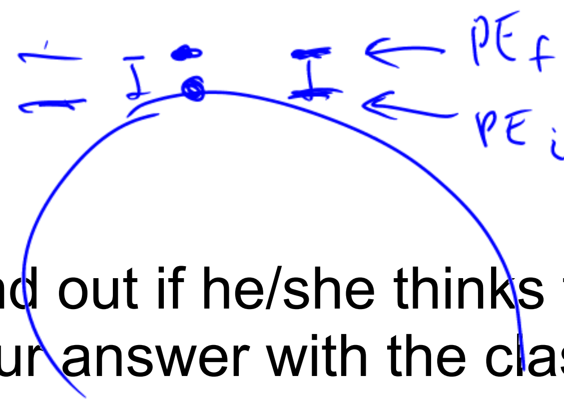



**Before:** PE = 0 when y = 0 (mgy)

**With new equation:** PE = 0 when r = ∞

# From warmup

Ralph noticed the negative sign in the general equation for gravitation potential energy, PE=−GMm/r, and he read the book's statement that "this expression reduces to PE=mgh close to the surface of Earth". He is very confused, because among other things one equation has a negative sign and the other one doesn't! How can they possibly be equivalent? What can you tell Ralph to help him out?




**"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.

# Worked problem

How much energy would you have to provide in order to “shoot” a 100 kg satellite into a near orbit like the ISS, 6712 km from center of earth? (E.g. via initial KE)

…into a much farther geostationary orbit? (42,157 km)

…to an orbit at the moon’s distance (381,715 km)

Answers: 3.29E9 J, 5.79E9 J, 6.21E9 J

# Escape velocity

Same question: …into an orbit very, very far away from the Earth?? (ignore the sun's gravitational pull)

*Hints:* What is its "orbital velocity" when $r = \infty$?
What is its final kinetic energy?
Final potential energy?

**Robert Heinlein:**

**"If you can get into orbit, then you're halfway to anywhere"**

Answers: 6.26E9 J

# From warmup

The "escape velocity" of a planet is the speed needed for a rocket to go from the surface of the planet into orbit.

a. true
b. false

# Worked Problem

What is the escape velocity of the earth?
($R_{earth}$ = 6371 km; $M_{earth}$ = 5.974 $\times$ $10^{24}$ kg)

Answer: 11.2 km/s