Announcements – 1 Oct 2013

HW 10: "No HW today"

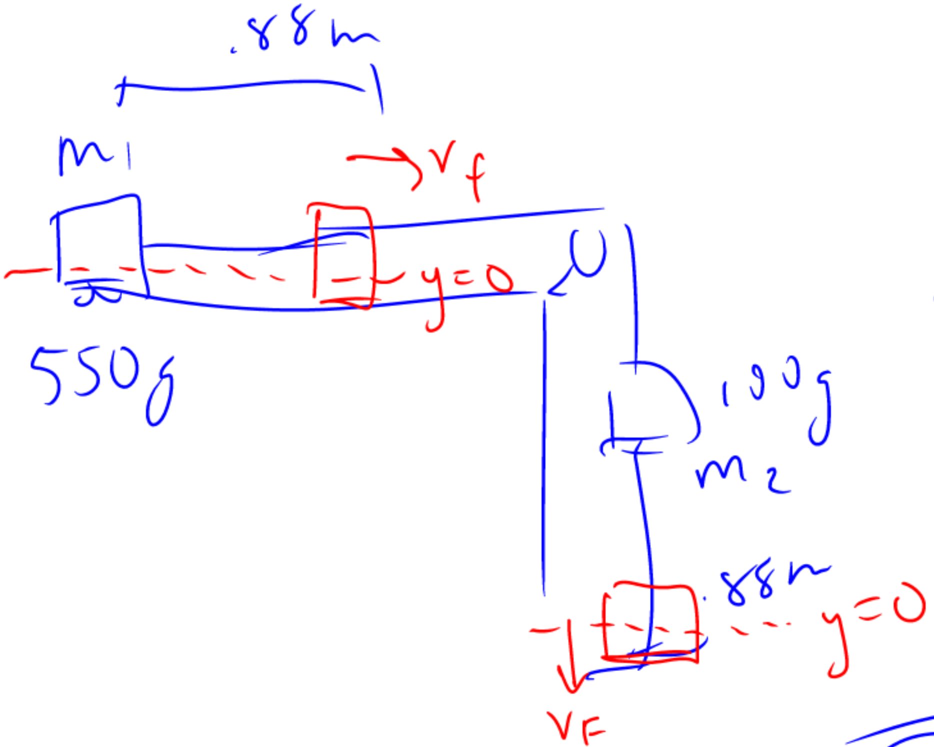
1. **Exam 2 is coming up!**
   a. Exam begins Thurs, ends next Wednesday, 2 pm (late fee after Tues, 2 pm)
   b. Covers Chapters 4 & 5, Homeworks 5-10
   c. Thursday lecture will be nearly 100% exam review
      i. Warmup quiz: pick out problems from a past exam
   d. TA-led exam review session:
      i. Time: ?? Thurs 7^{30} – 9 pm
      ii. Place: ??

Notes I consider all exams to be cumulative, to some extent:

- You will very likely get ~~1-3~~ 2 problems problems from exam 1 as repeats (different numbers)
- You will very likely have some problems where you use Newton's 2nd Law to find acceleration then kinematics equations to find more details
- Newton's 2nd Law problems involving springs (today's topic, another item for our "bag of tricks") are certainly fair game.

Demo: Cart being pulled on track

Demo problem: Dr Colton hangs a __.1__ kg mass from a pulley and attaches it to a __.55__ kg cart with a string. He lets the hanging mass fall __.88__ m. How fast is the cart going at the end?



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

$$(PE_1 + KE_1 + PE_2 + KE_2)_{bef} = (PE_1 + KE_1 + PE_2 + KE_2)_{aft}$$

$$m_2 g h = \tfrac{1}{2} m_1 v_f^2 + \tfrac{1}{2} m_2 v_f^2 = \tfrac{1}{2}(m_1 + m_2) v_F^2$$

$$\sqrt{\frac{2 m_2 g h}{m_1 + m_2}} = v_F$$

$$v_F = \sqrt{\frac{2(.1)(9.8)(.88)}{.55 + .1}}$$

$$v_F = 1.63 \text{ m/s}$$

Pole Vaulters

Video: Pole Vaulter

Q: How high can pole jumpers jump?

(Simple Analysis)

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

Compare: Pole vault world record: 6.14 m (Sergey Bubka, 1994)

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

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

$(PE_g + KE)_{bef} = (PE_g + KE)_{aft}$

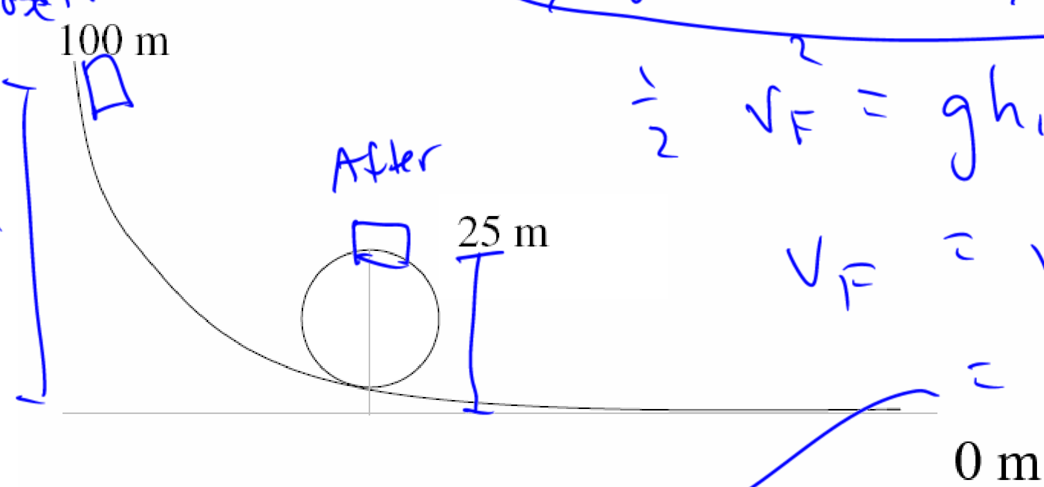
$mgh_1 = mgh_2 + \frac{1}{2} m v_f^2$

$\frac{1}{2} v_F^2 = gh_1 - gh_2$

$v_F = \sqrt{2(gh_1 - gh_2)}$

$= \sqrt{2(9.8)(100-25)}$

$= 38.3 \text{ m/s}$



$\sqrt{2 \cdot 9.8 \cdot (75-0)}$

Could you do this with N2??

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

1. Draw "before" and "after" pictures.
   1b. If non-conservative forces: draw a "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 all non-conservative forces (often friction). If needed, use the FBD and N2 to figure out the force.

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

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

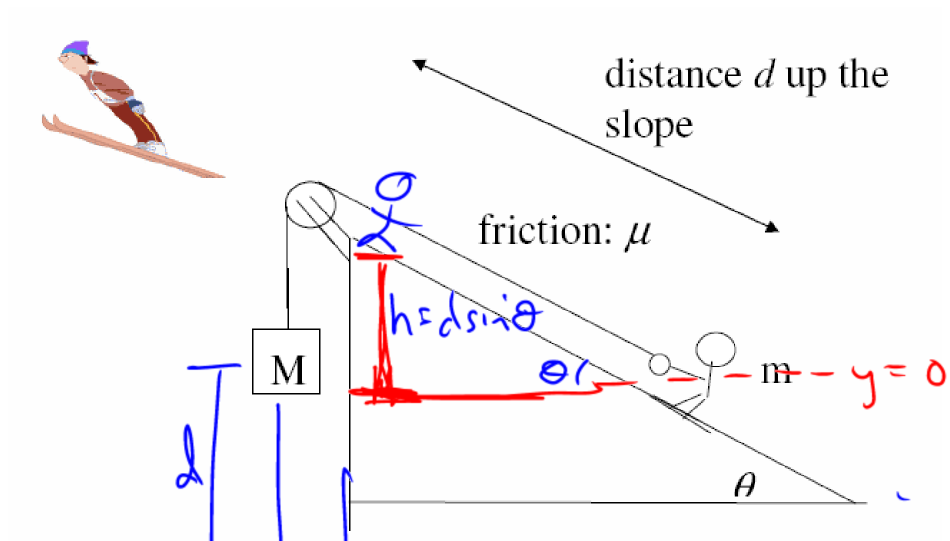
$$PE_{grav} = mgy$$

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

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

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

Problem: In terms of M, m, μ, d, and θ, what is his takeoff speed?



Pictures:

During: T, N, $f = \mu N$, mg

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

$(PE_M + KE_M + PE_m + KE_m)_{bef} + W = (PE_M + KE_M + PE_m + KE_m)_{aft}$

Fill in:

$$Mgd - \mu\,d = mg(d\sin\theta) + \tfrac{1}{2}(M+m)v_f^2$$

Plug in given quantities:

$\Sigma F_y = 0 \rightarrow N = mg\cos\theta$

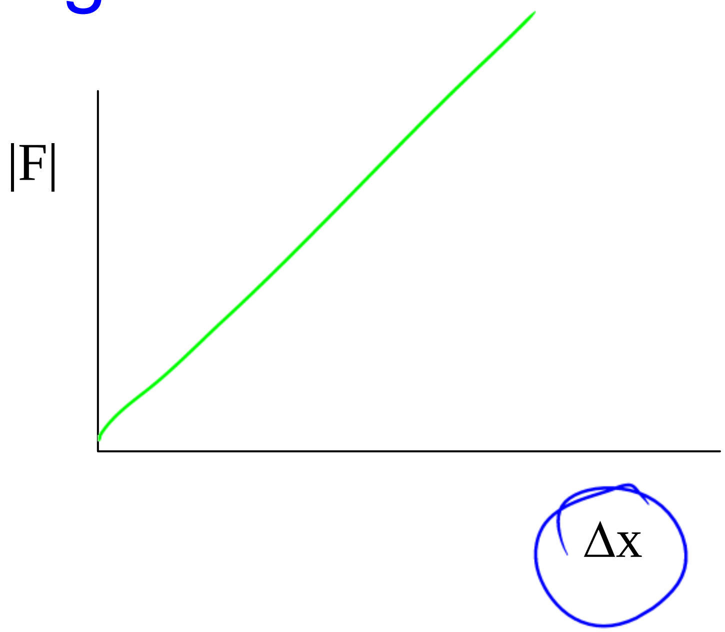
$$Mgd - \mu(mg\cos\theta)d = mg(d\sin\theta) + \tfrac{1}{2}(M+m)v_f^2$$

$$\frac{2(Mgd - \mu mg\cos\theta\, d - mgd\sin\theta)}{M+m} = v_f^2$$

Solve for what you want:

$v_f = \sqrt{\;\;}$

Springs



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

$$F_{spring} = -kx$$

(negative sign: force acts opposite displacement: it pulls/ pushes back to resting point)

Caution: x must be measured from equilibrium

Springs are conservative

$$PE_{spring} = ½\, kx^2$$

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

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

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

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

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

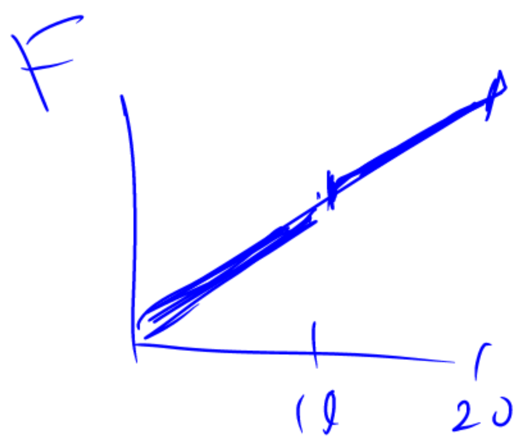
From warmup

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



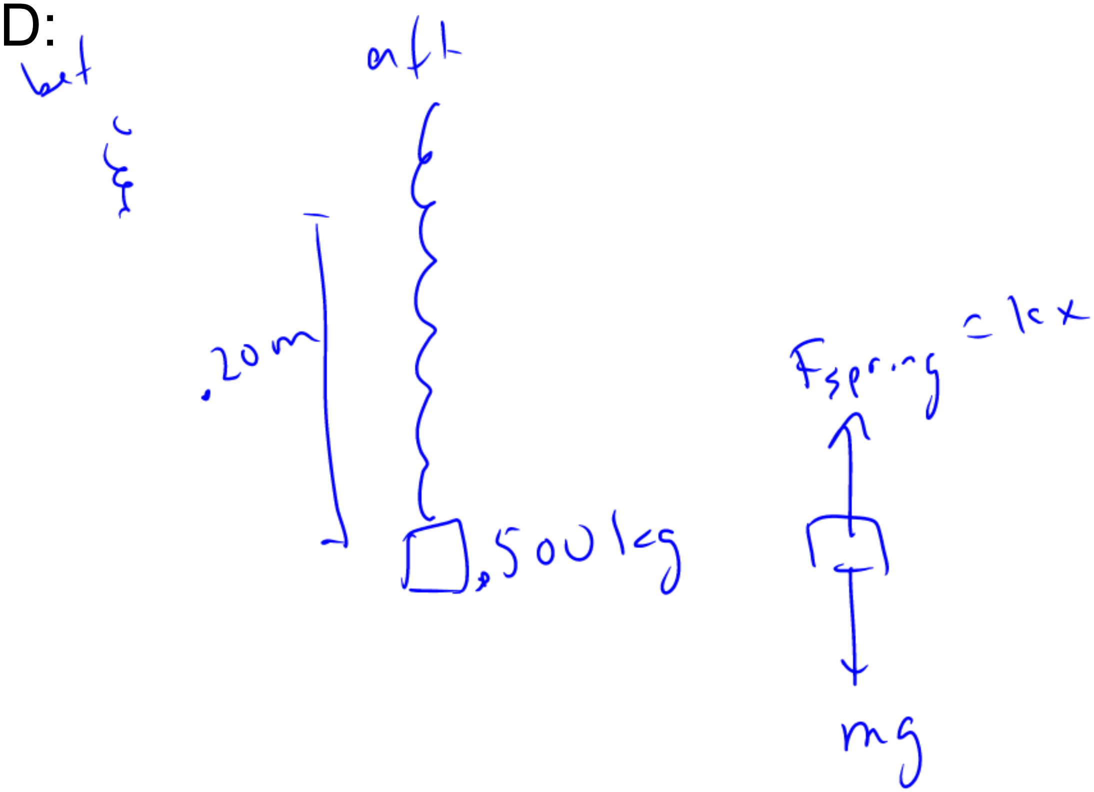
Experimental Problem

units? $F = kx$, $k = \frac{F}{x} = \frac{N}{m}$

Determine the spring constant of a hanging spring.

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

FBD:



$\sum F = 0$

$kx - mg = 0$

$k = mg/x$

$= \frac{(.5)(9.8)}{(.20)} = 24.5\ \frac{N}{m}$

Same Problem: Determine the spring constant of a hanging spring.

Method 2: Use energy (suddenly moving spring; compare starting point to lowest point of oscillation)

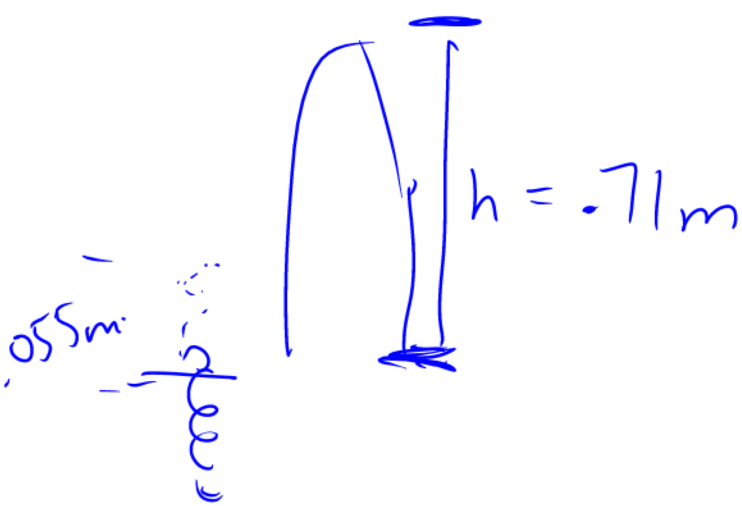
before

after

Problem: Determine the spring constant of the spring inside the “vertical cannon cart”

Method 3: Spring PE converted to gravity PE

$m = .015\ kg$



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

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

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

$$= \frac{2(.015)(9.8)(.71)}{(.055)^2}$$

$$= 69\ N/m$$

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

Power!

The rate at which energy is produced or consumed

$$P = \frac{\Delta E}{\Delta t}$$

Or… (equivalently)

Power is the rate at which work is being done

SI units: 1 Watt = 1 J/s = 1 N·m/s = 1 kg·m^2/s^3 (yuck!)

Unit conversion: 1 horsepower (hp) = 746 W

Another useful formula, if constant velocity: $P = F_{//} v$

Derivation: $P = \frac{\Delta E}{\Delta t}$

$$= \frac{W_{net}}{\Delta t}$$

$$= \frac{F_{//} \Delta x}{\Delta t}$$

$$= F_{//} \cdot v$$

Image credit: Wikipedia. (Northern end of Stelvio Pass, Italy)

From warmup: Switchbacks on mountain roads (consider only work done against gravity):

a. increase the work needed to go up a mountain

b. decrease the work needed to go up a mountain

c. keep the work needed the same

Experimental Problem

How much "horsepower" can a person generate?

Experiment: jumping from a stand-still $\rightarrow$ Volunteer needed!

Parameters:

mass (kg) = ________

measured height jumped (m) = _________

measured "impulse time" (s) (time while legs are exerting force on ground)

= ________

What was the work done by his/her body during the impulse time?

How much horsepower?

Clicker quiz

A car weighing 3000 N moves at a speed of 30 m/s on level ground. To do this, it pushes backwards on the road with a 5000 N force. What is the power output of the car engine?

a. 0 kW
b. 60 kW
c. 90 kW
d. 150 kW
e. 240 kW

→ Where does this power go? If the car moves at constant speed, it's not used to accelerate the car.

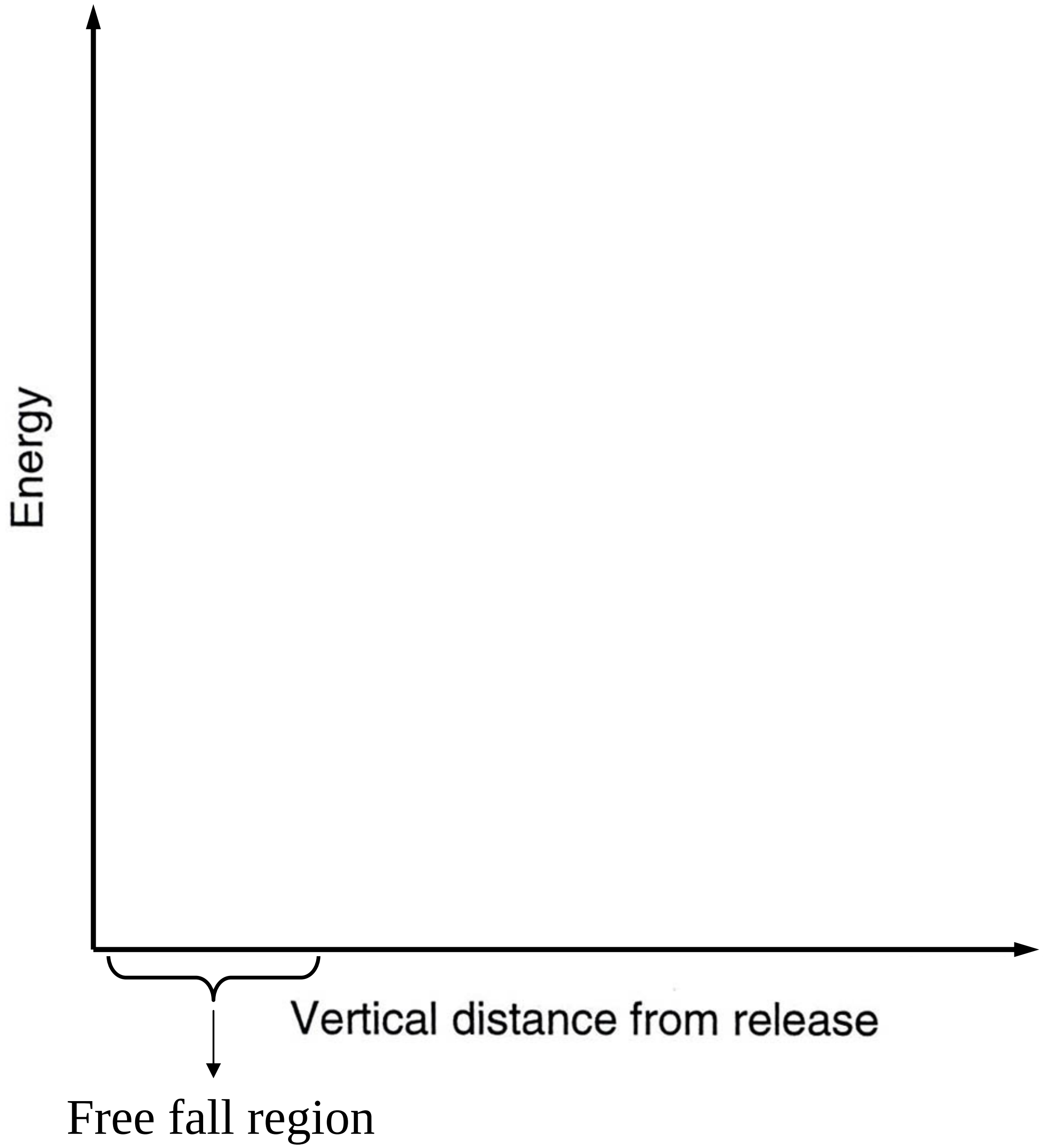
From warmup

Ralph sees that his car's engine is rated at 100 hp. He thinks, "Cool, this means if I ever get in a tug of war with 90 horses, I will win!" Is he thinking about this correctly? What should you tell him?

“Pair share”–I am now ready to share my neighbor’s answer if called on.

a. Yes

Bungee jumping: types of energy



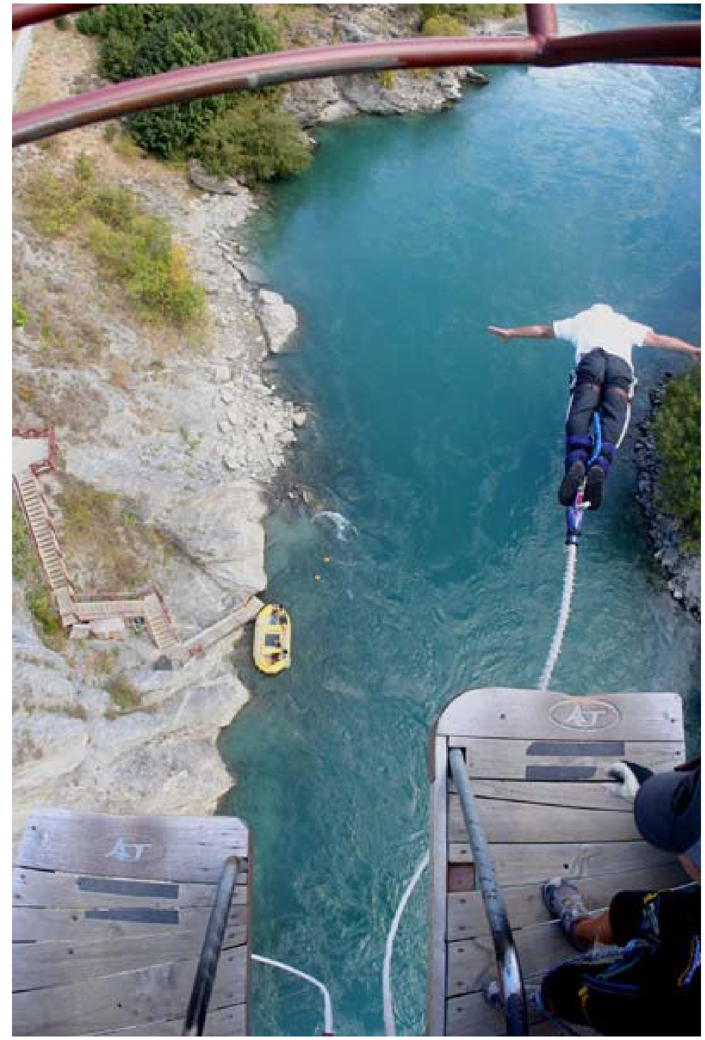
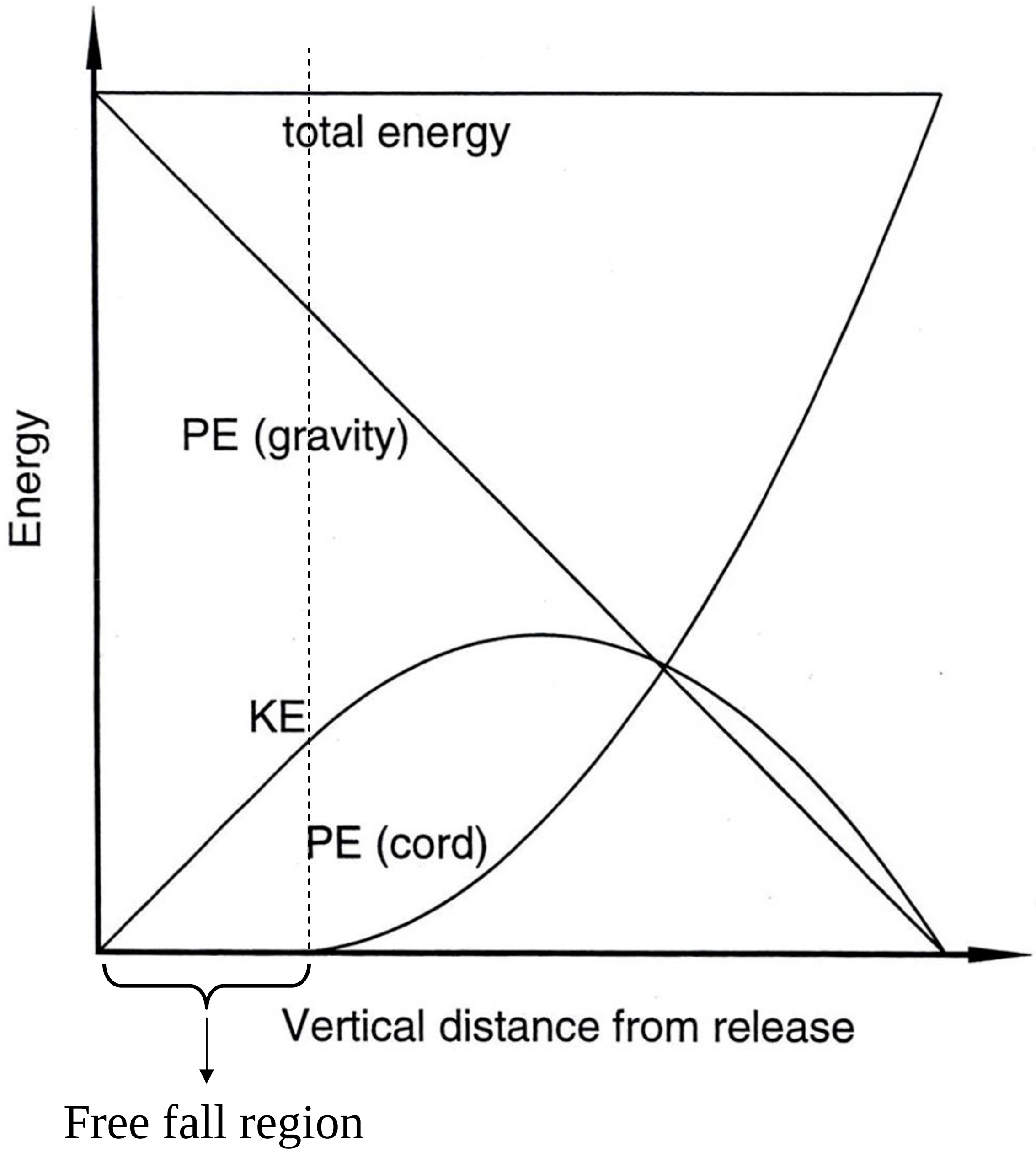


Image credit: Wikipedia


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