University Physics 226N/231N
Old Dominion University

Energy Conservation, Potentials, Energy Diagrams

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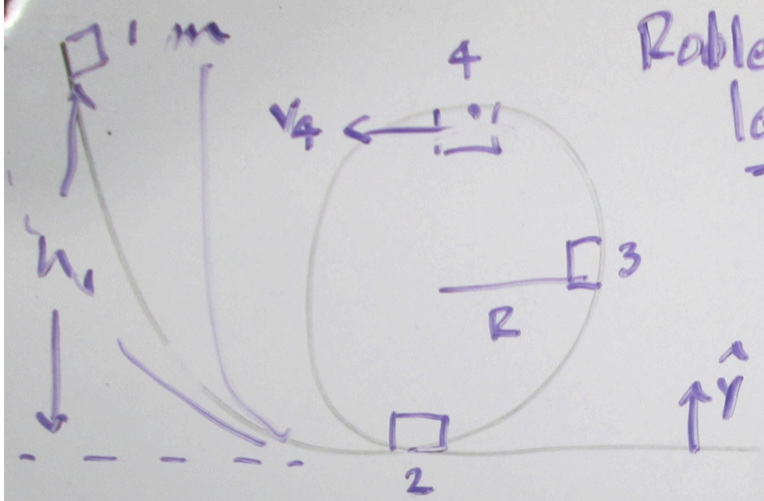
Reminder: The Second Midterm will be Weds Oct 19 2016

Happy Birthday to Neil deGrasse Tyson, Sean Carroll,
Robert Goddard, Kate Winslet, Ray Kroc, and Vaclav Havel!
The 2016 Physics Nobel prize was awarded yesterday!!

Please set your cell phones to "vibrate" or "silent" mode. Thanks!

Reminder: Loop the Loop



Roller coaster loop: start $v=0$

what h_1 necessary to just barely make it around the loop?

$n_4 = 0\,N$

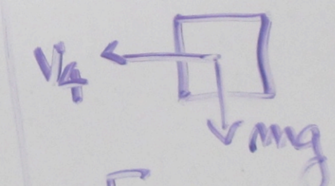
Energy term	1	4
PE_g	mgh_1	$mg\cdot 2R$
KE	0	$\frac{1}{2}mv_4^2$

$$\Rightarrow \cancel{m}gh_1 = \cancel{m}g\cdot 2R + \frac{1}{2}\cancel{m}v_4^2$$

2 unknowns! v_4, h_1

→ Circular motion

$v_4 \sim$ constant



$$a = \frac{v_4^2}{R}$$

$$F_{net} = \cancel{m}g = \cancel{m}a = \frac{v_4^2}{R}$$

$$\Rightarrow \boxed{v_4 = \sqrt{Rg}}$$

$$\cancel{g}h_1 = 2R\cancel{g} + \frac{1}{2}\cdot R\cancel{g} \Rightarrow \boxed{h_1 = \frac{5}{2}R}$$

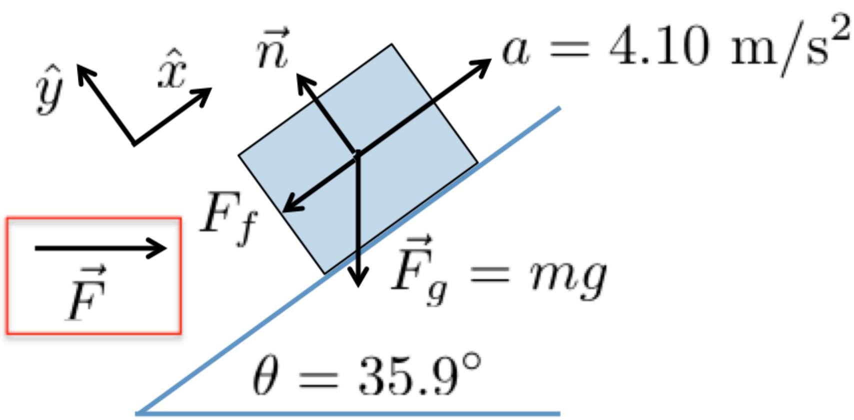
Loop the Loop Demo (Hot Wheels!)

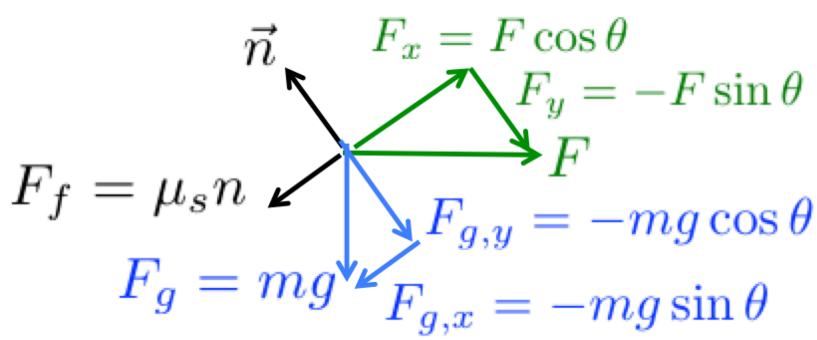
Review: Solution to Homework 5.72

A 5.00-kg box sits on a ramp that is inclined at 35.9 ° above the horizontal. The coefficient of kinetic friction between the box and the ramp is 0.27.

Part A

What *horizontal* force is required to move the box up the incline with a constant acceleration of 4.10 $\mathrm{m/s^2}$?





Newton's 2nd law y:

$$n + F_{g,y} + F_y = 0 \qquad n = mg\cos\theta + F\sin\theta$$

Newton's 2nd law x:

$$F_x + F_{g,x} + F_f = ma$$

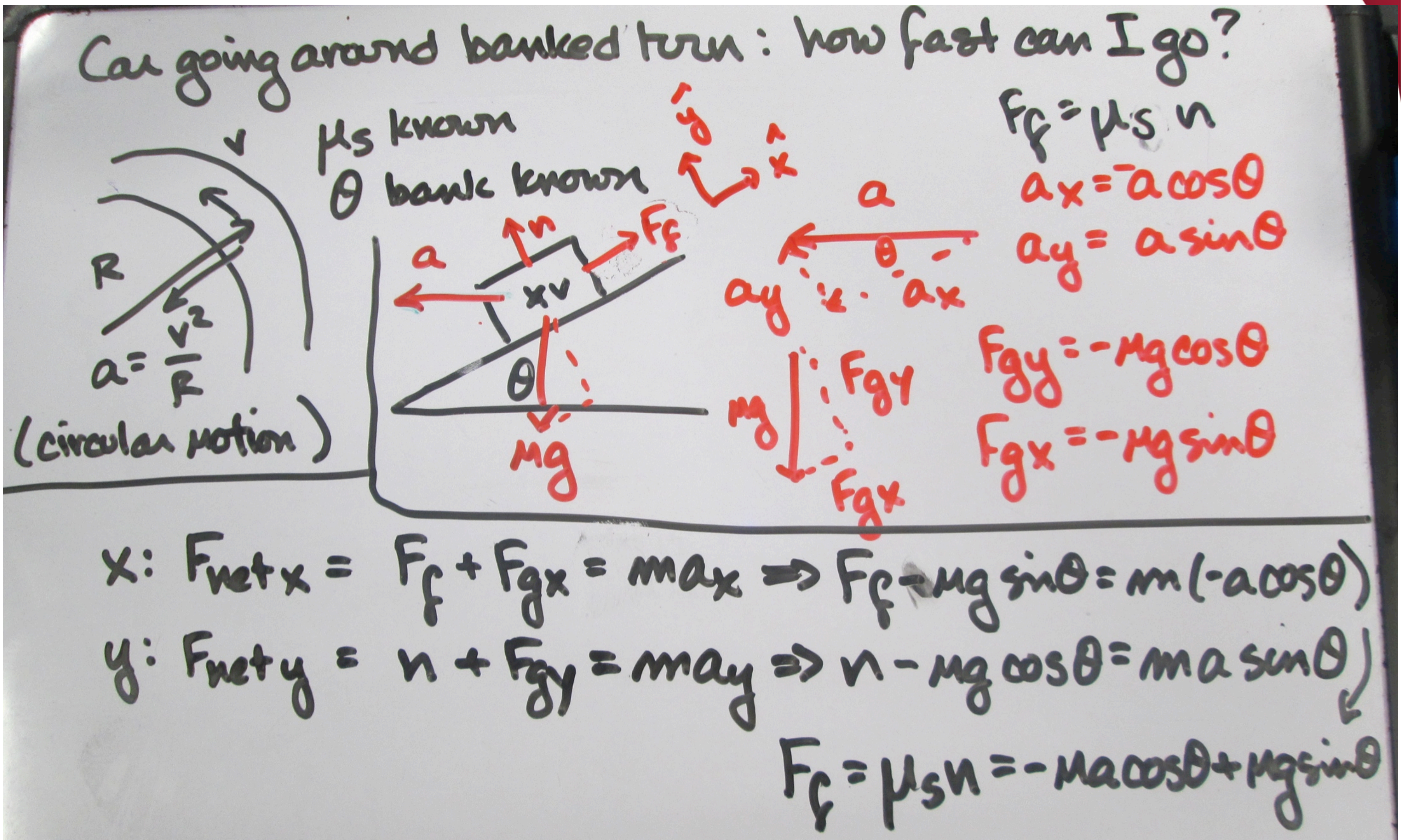
$$F\cos\theta - mg\sin\theta = \mu_s n = ma$$

$$F\cos\theta - mg\sin\theta - \mu_s(mg\cos\theta + F\sin\theta) = ma$$

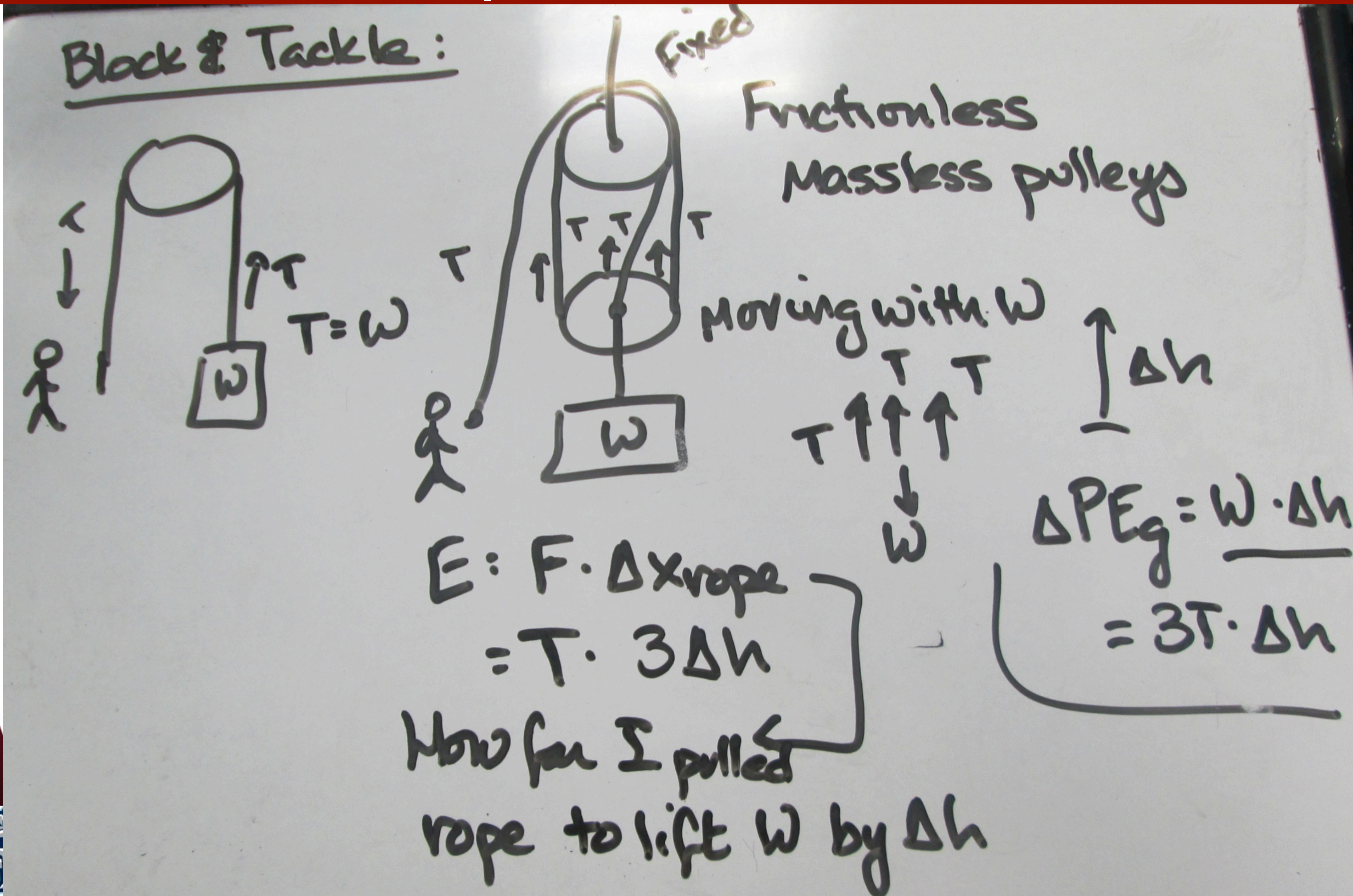
$$F(cos\theta - \mu_s\sin\theta) - mg\sin\theta - \mu_s mg\cos\theta = ma$$

$$F = \frac{ma + mg\sin\theta + \mu_s mg\cos\theta}{\cos\theta - \mu_s\sin\theta} = 91.98\ \mathrm{N}$$

Example: Car Going Around a Banked Turn

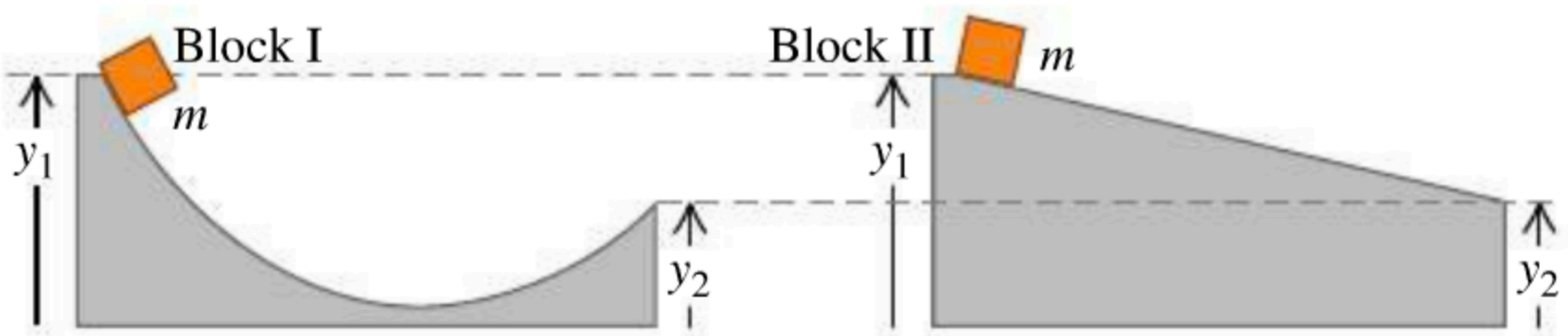


Example: Block and Tackle



Review: Energy Conservation

- Assume a frictionless system
  - Is the block's speed at y_2 the same in both cases?



- Now add a bit of friction…
  - Is the block's speed at y_2 the same in both cases this time?
  - Why?

Conservative and NonConservative Forces

Friction: Energy loss is path dependent

General term: Nonconservative

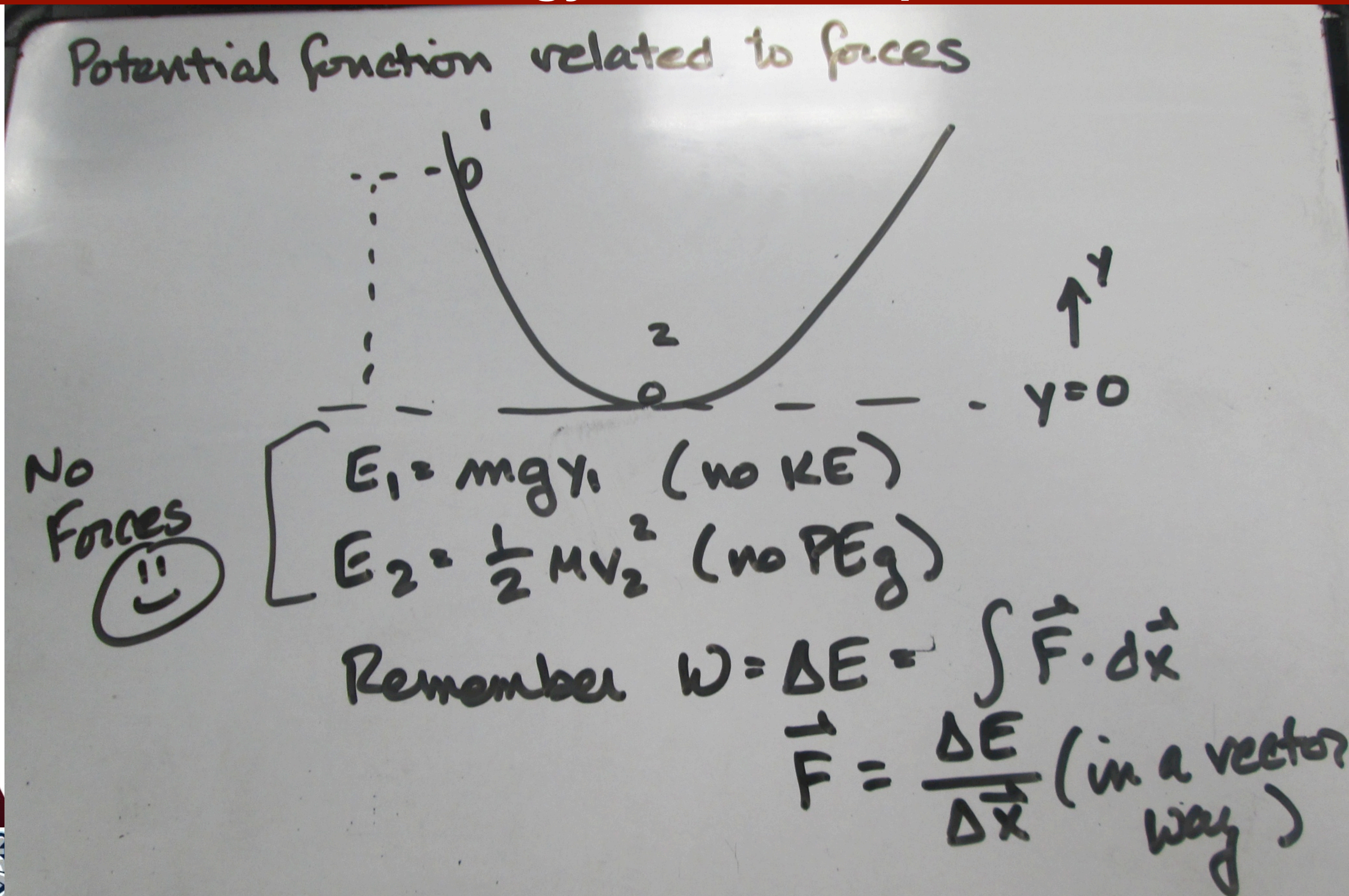
$$E_f = \vec{F}_f \cdot \Delta\vec{x}$$
$$= \vec{n}(x) \cdot \mu_k \cdot \Delta\vec{x}$$

Conservative forces: change in energy is not path dependent

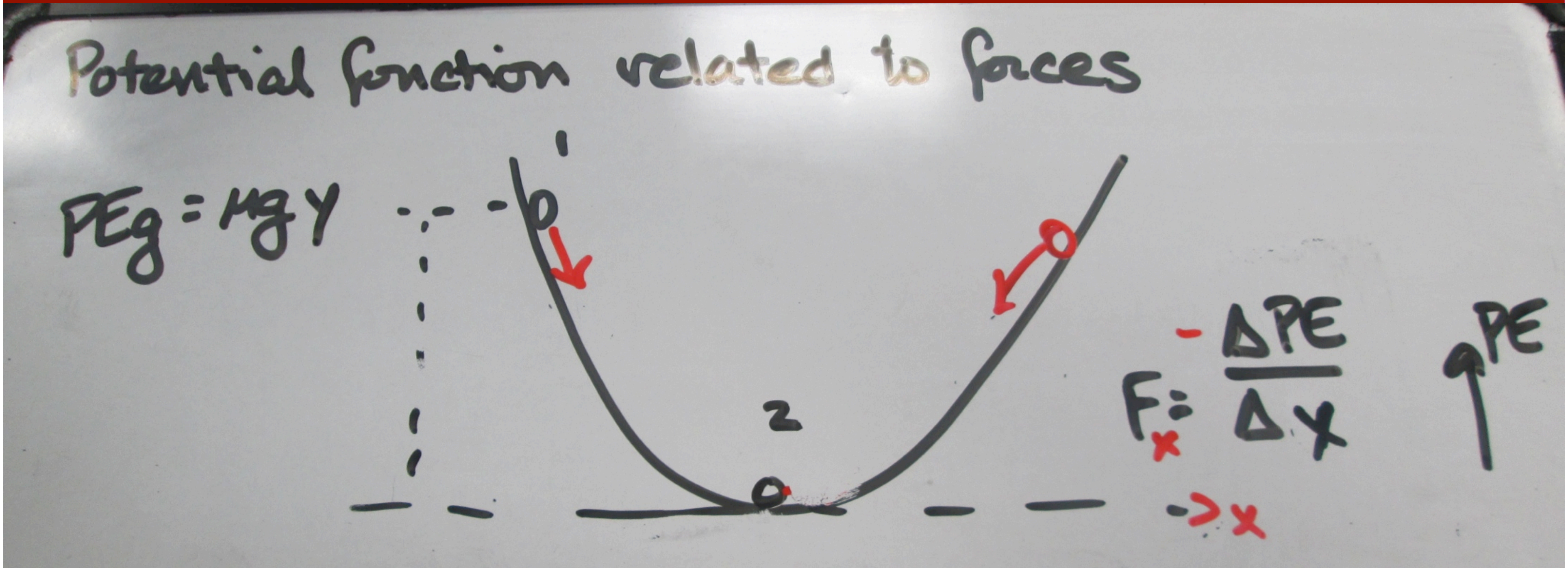
- Gravity
- Elec & Magnetism
- Ideal springs

$\Rightarrow$ Potential function

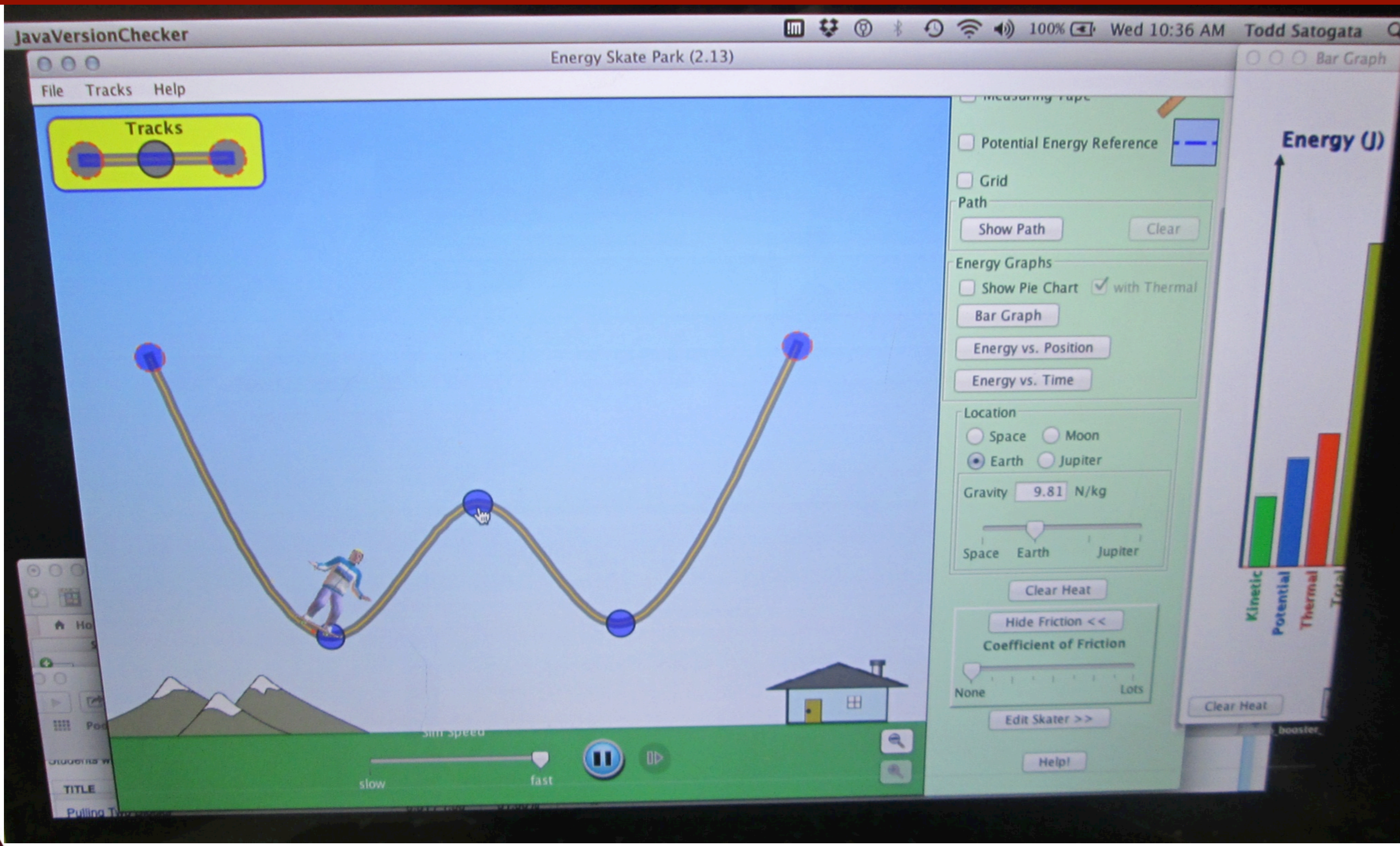
Potential Energy Relationship to Forces



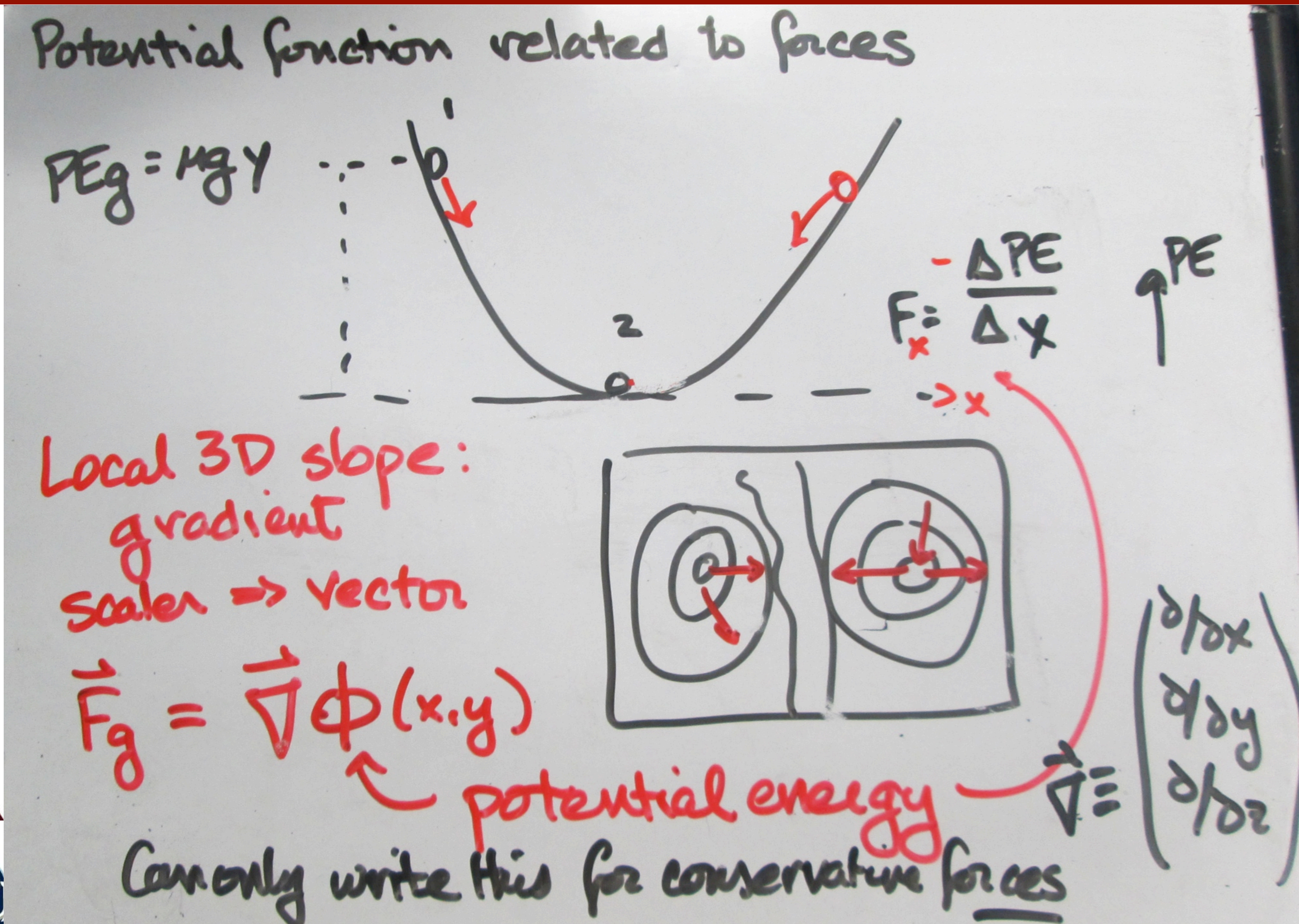
Potential Function Relationship to Force: 1D



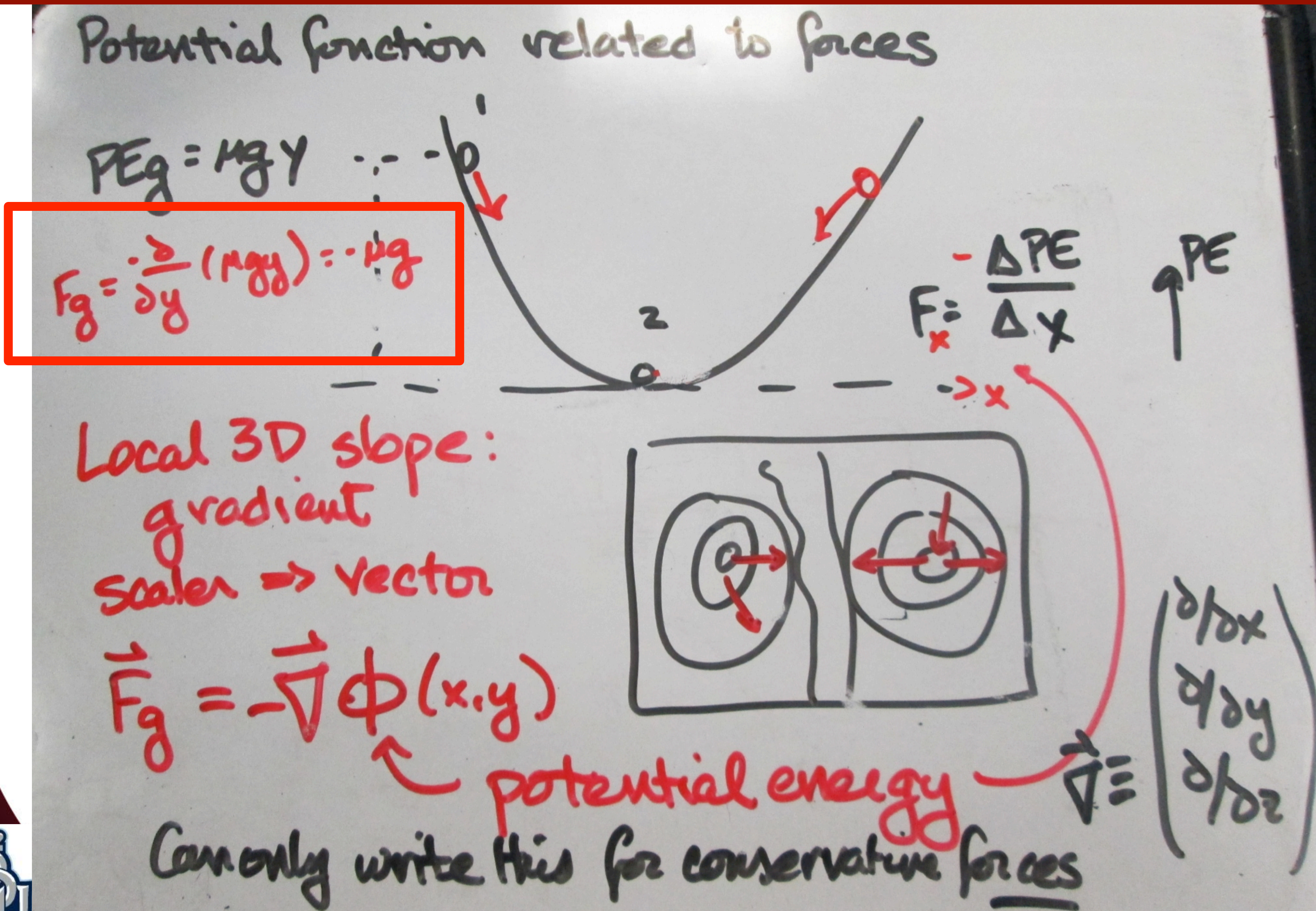
Skate Park Demo



Back to Potentials and Forces



Back to Potentials and Forces

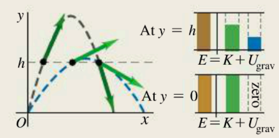


Energy Diagrams

- Skate park example

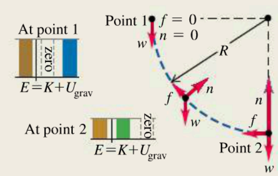
When total mechanical energy is conserved: The total potential energy U is the sum of the gravitational and elastic potential energies: $U = U_{grav} + U_{el}$. If no forces other than the gravitational and elastic forces do work on a particle, the sum of kinetic and potential energies is conserved. This sum $E = K + U$ is called the total mechanical energy. (See Examples 7.1, 7.3, 7.4, and 7.7.)

$$K_1 + U_1 = K_2 + U_2 \qquad (7.4), (7.12)$$



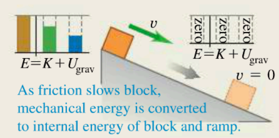
When total mechanical energy is not conserved: When forces other than the gravitational and elastic forces do work on a particle, the work W_{other} done by these other forces equals the change in total mechanical energy (kinetic energy plus total potential energy). (See Examples 7.2, 7.5, 7.6, 7.8, and 7.9.)

$$K_1 + U_1 + W_{other} = K_2 + U_2 \qquad (7.14)$$



Conservative forces, nonconservative forces, and the law of conservation of energy: All forces are either conservative or nonconservative. A conservative force is one for which the work–kinetic energy relationship is completely reversible. The work of a conservative force can always be represented by a potential-energy function, but the work of a nonconservative force cannot. The work done by nonconservative forces manifests itself as changes in the internal energy of bodies. The sum of kinetic, potential, and internal energies is always conserved. (See Examples 7.10–7.12.)

$$\Delta K + \Delta U + \Delta U_{int} = 0 \qquad (7.15)$$

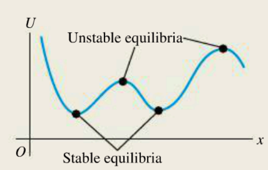


Determining force from potential energy: For motion along a straight line, a conservative force $F_x(x)$ is the negative derivative of its associated potential-energy function U. In three dimensions, the components of a conservative force are negative partial derivatives of U. (See Examples 7.13 and 7.14.)

$$F_x(x) = -\frac{dU(x)}{dx} \qquad (7.16)$$

$$F_x = -\frac{\partial U}{\partial x} \qquad F_y = -\frac{\partial U}{\partial y} \qquad F_z = -\frac{\partial U}{\partial z} \qquad (7.17)$$

$$\vec{F} = -\left(\frac{\partial U}{\partial x}\hat{\imath} + \frac{\partial U}{\partial y}\hat{\jmath} + \frac{\partial U}{\partial z}\hat{k}\right) = -\vec{\nabla} U \qquad (7.18)$$



Another Homework Solution