College Physics I: 1511 Mechanics & Thermodynamics

Professor Jasper Halekas
Van Allen Lecture Room 1
MWF 8:30-9:20 Lecture

Announcements

- Everyone is now aware that Turning Point Cloud sucks!
  - Many people have been having all kinds of technological issues
  - Many issues are now fixed but perhaps not all
- To account for this, I will bump everyone's participation points up by +2 at the end of the semester
  - Given ~40 lectures, this effectively increases everyone's participation score by 5%

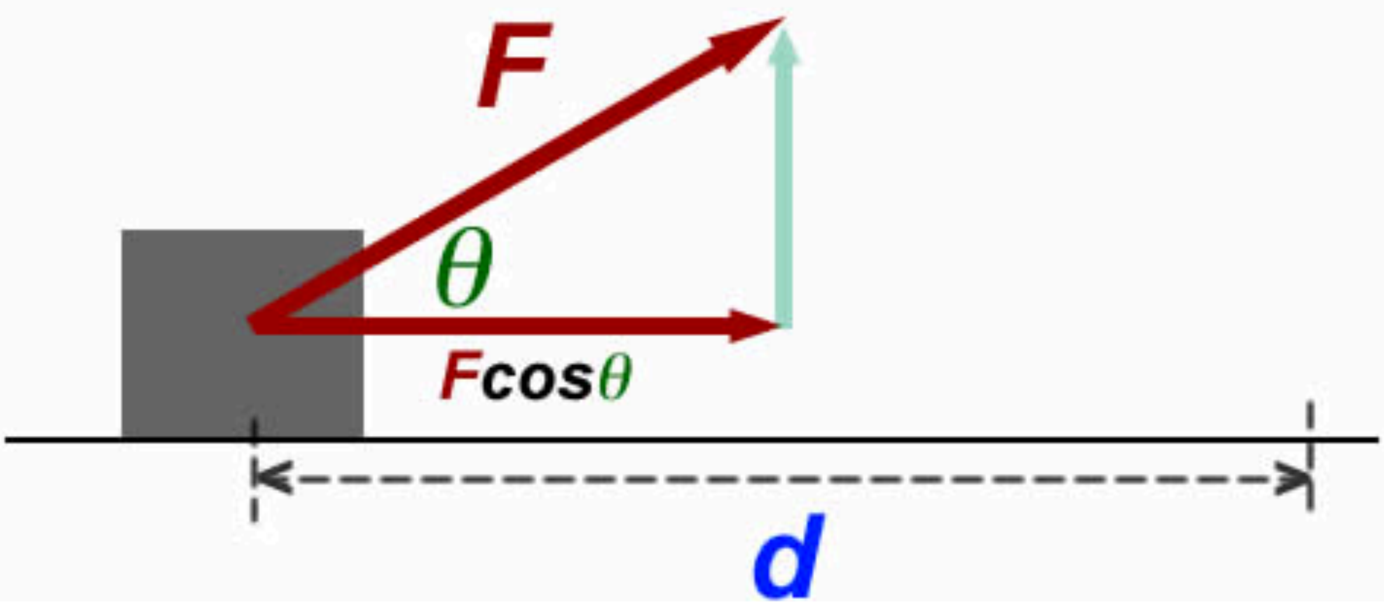
Kinematics Equation #4

$$v^2 = v_0^2 + 2a\Delta x$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mv_o^2 = F^{net}\Delta x$$

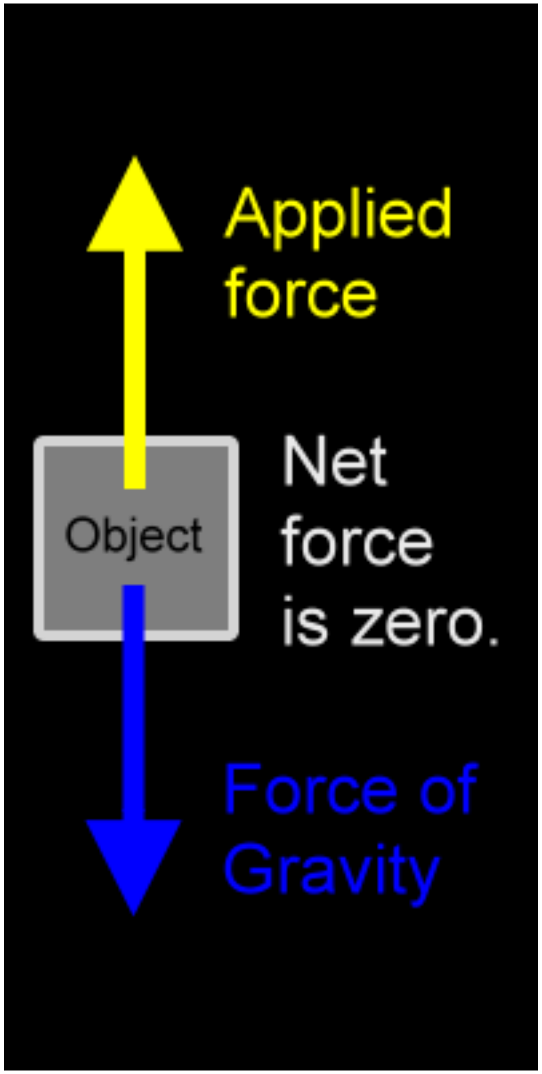
Work

$$W = Fd\cos\theta$$



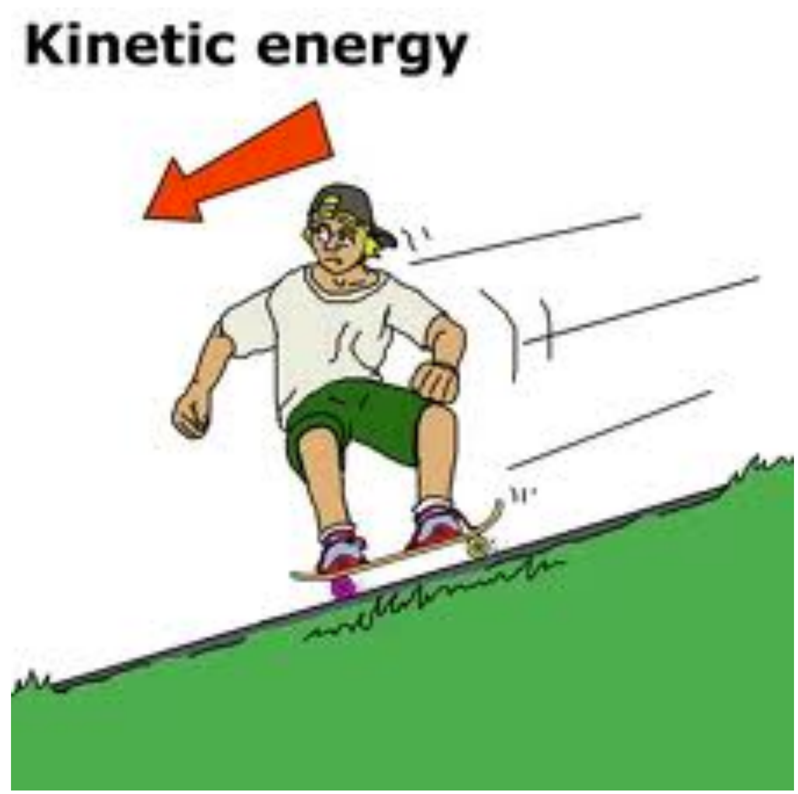
Work Done to Lift an Object

- Work done by gravity when lifting a body to height h
  - W_g = -mgh
  - Gravity opposes motion
- Work done by me to overcome gravity
  - $W_{applied}$ = mgh
  - I have to do work to lift



Definition: Kinetic Energy

- Kinetic energy =
  $1/2\ m\ v^2$
- Any body in motion has kinetic energy
- Kinetic energy scales linearly with mass, and with the square of the velocity
- Kinetic energy has units of $[kg][m^2]/[s^2] = [N][m] = [J]$



Work-Energy Theorem

- When a net external force does work on an object, the net work is equal to the change in kinetic energy of the object
  - $W_{net} = KE_f - KE_o$
    $= 1/2mv_f^2 - 1/2\ mv_o^2$
  - Work is an increment of energy

Concept Check

- Two marbles, one twice as heavy as the other, are dropped to the ground from the roof of a building. (Assume no air resistance.) Just before hitting the ground, the heavier marble has..

A. As much kinetic energy as the lighter one.
B. Twice as much kinetic energy as the lighter one.
C. Half as much kinetic energy as the lighter one.
D. Four times as much kinetic energy as the lighter one.
E. Impossible to determine.

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$\boxed{\text{Marbles}}$

$$W_g = mgd$$

$$= \Delta KE$$

$$= \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_0^2$$

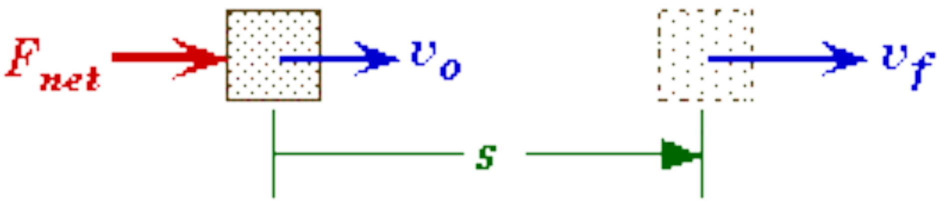
$$= \tfrac{1}{2}mv^2$$

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

so $KE \propto m$

Work Can be Positive or Negative

$$KE_o = \frac{1}{2} m v_o^2 \qquad KE_f = \frac{1}{2} m v_f^2$$



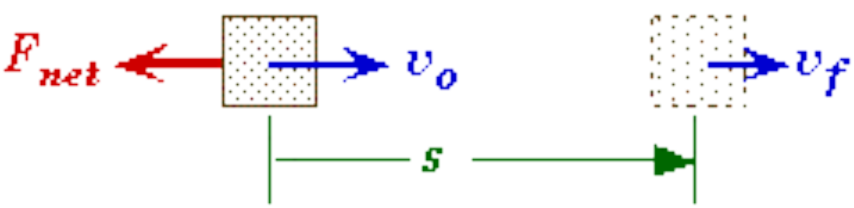
$$W_{net} = F_{net}\, s \cos(0^o) = +F_{net}\, s$$

$W_{net} > 0$

$\Delta v > 0$

$KE_f > KE_o$

$$KE_o = \frac{1}{2} m v_o^2 \qquad KE_f = \frac{1}{2} m v_f^2$$



$$W_{net} = F_{net}\, s \cos(180^o) = -F_{net}\, s$$

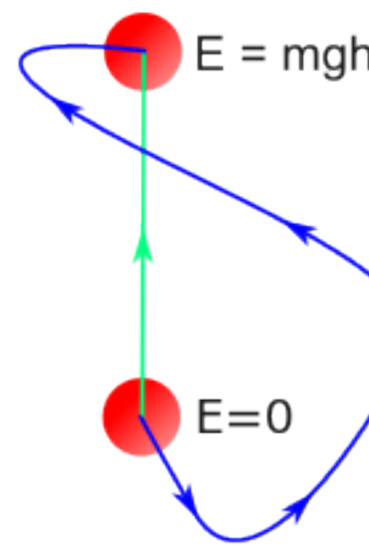
$W_{net} < 0$

$\Delta v < 0$

$KE_f < KE_o$

Work of Gravity

- The work done by gravity only depends on the difference in heights from initial to final position
  - Vertical motion takes the same amount of work as motion up a ramp that reaches the same height
  - In fact, it is the case that no matter what path you carry an object on, the work done by gravity only depends on the mass and the difference in heights



Concept Check

- Suppose you want to ride your mountain bike up a steep hill. Two paths lead from the base to the top, one twice as long as the other. (Neglect friction i.e. consider only your "fight against gravity”). Compared to the average force you would exert if you took the short path, the average force you exert along the longer path is

- A: four times smaller.
- B: half as big.
- C: twice as big.
- D: the same.
- E: undetermined—depends on time taken.

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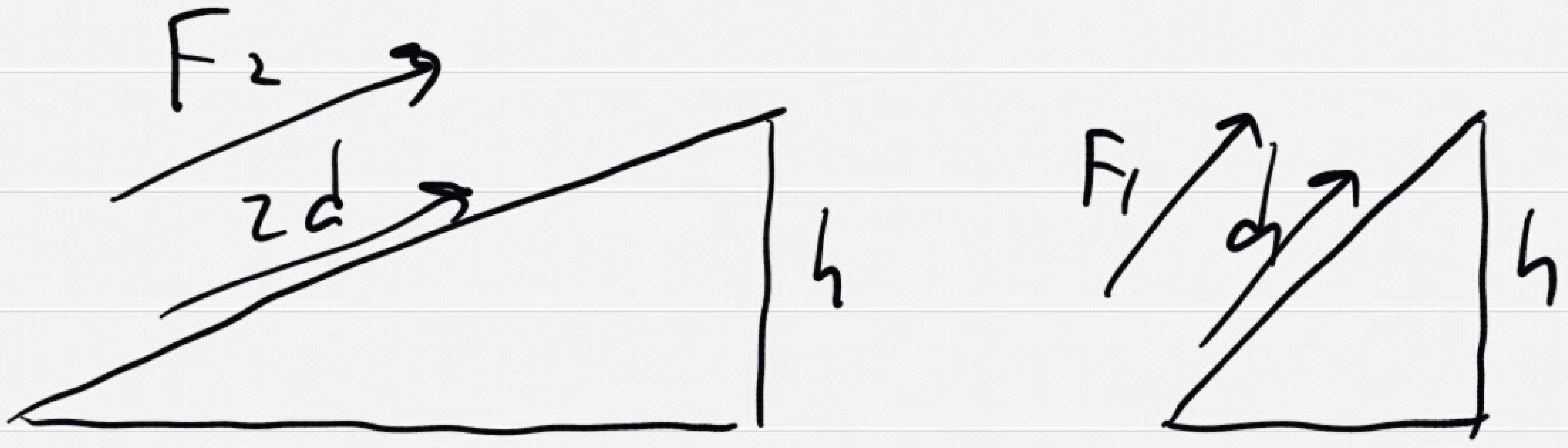
$\boxed{\text{Mountain Bike}}$



$W = mgh$ in both cases

$W = F_1 \cdot d = F_2 \cdot 2d$

$F_2 \cdot 2 = F_1$

$$\boxed{F_2 = F_1/2}$$

Work of Gravity

- The work done by gravity is also **reversible**
  - If you lift a body up and then let it back down to the same height, gravity does equal and opposite work on the upward and downward trips

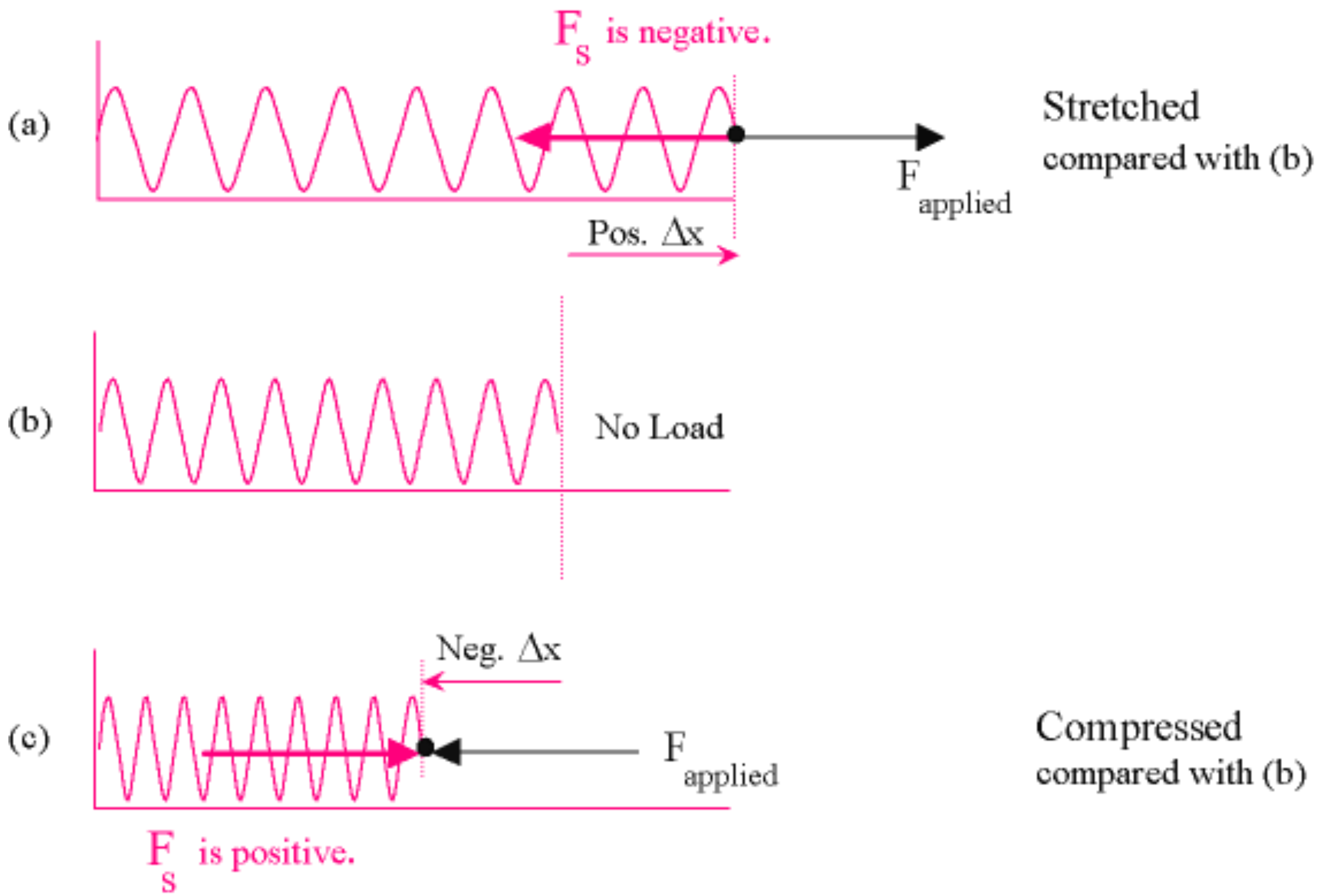
$W_g = -mgh$

$W_g = +mgh$

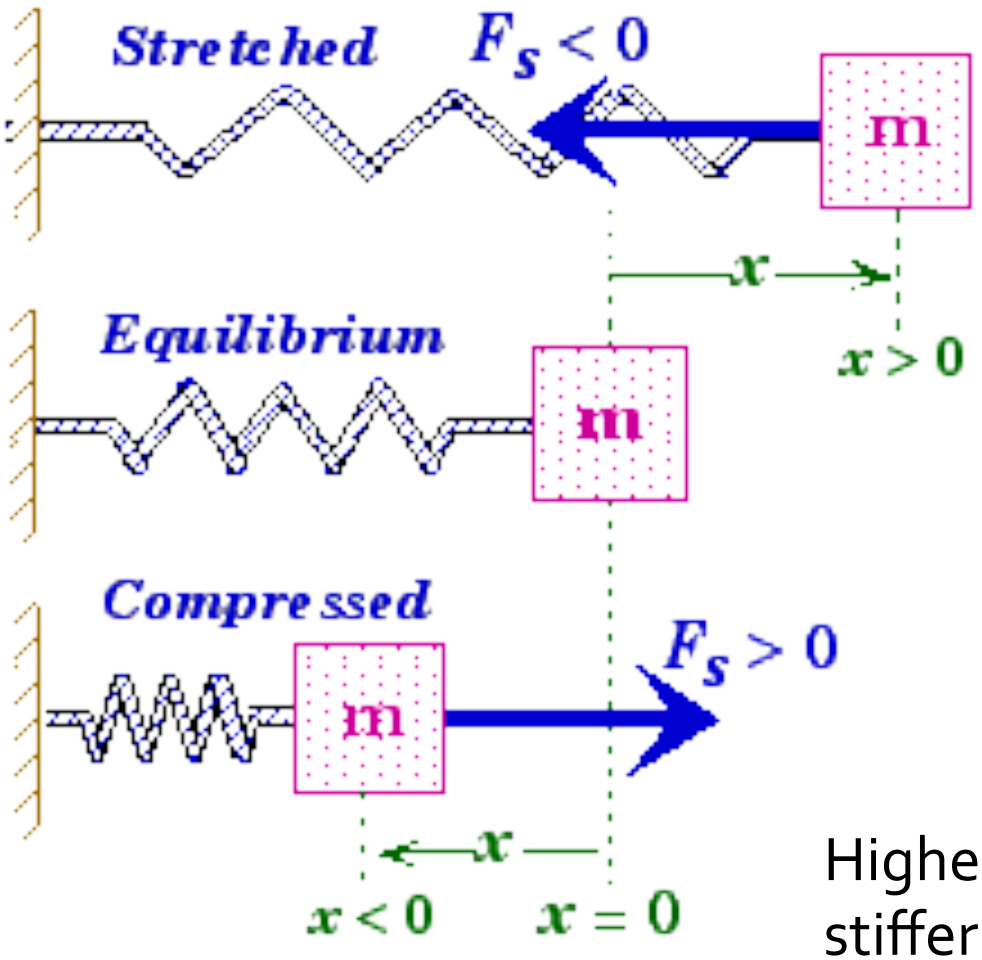
Conservative Forces

- Any force that has these two properties is a **conservative** force
  - Reversible
  - Work does not depend on path

Springs (Also Conservative)



Spring Force (Hooke's Law)



$$F_s = -k\,x$$

Higher spring constant k = stiffer spring

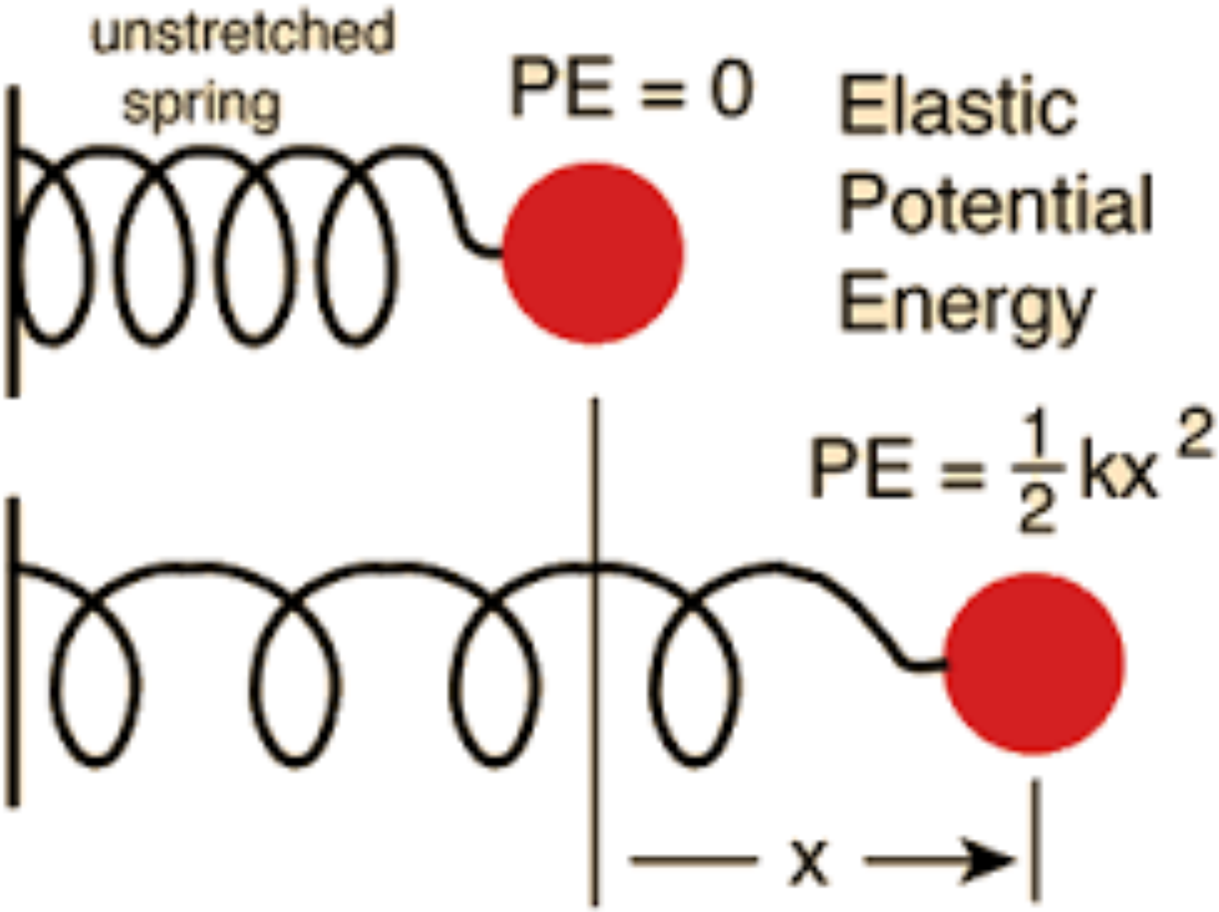
Potential Energy

- Any conservative force has a "potential energy" associated with it
- Potential energy U or PE is defined such that:
  - $W = -\Delta U = -\Delta PE = PE_o - PE_f$
- Important note: The "zero" of potential energy is arbitrary – you are always free to add or subtract a constant to potential energy

Gravitational Potential Energy

- $W = -mgh = -mg\Delta y = -\Delta PE$
  - $\Delta PE_g = mg\Delta y = mgh$

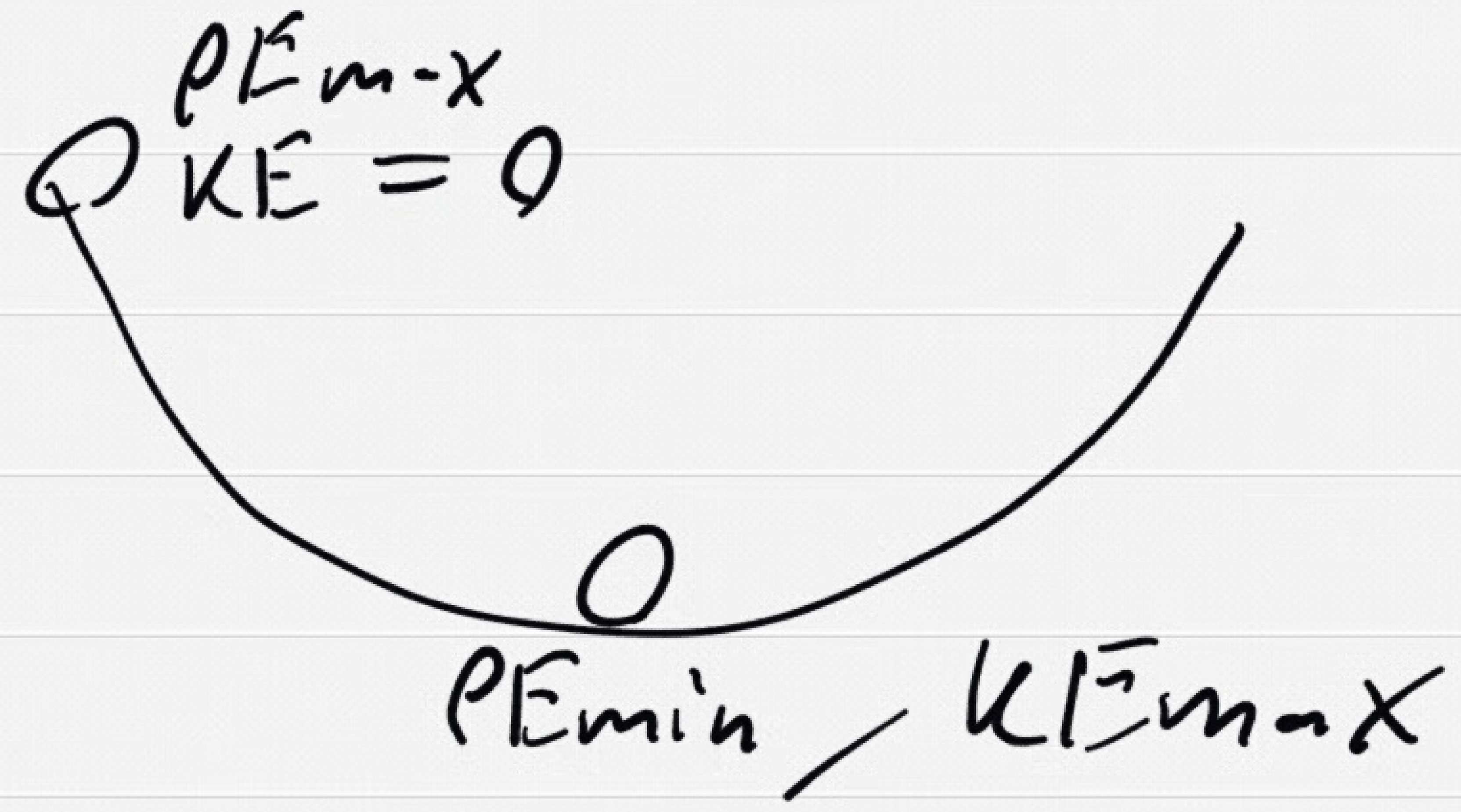
Spring Potential Energy



Conservation of Energy

- $W = KE_f - KE_o$
- $W = PE_o\text{-}PE_f$ (True only for conservative forces)
- $KE_f - KE_o = PE_o\text{-}PE_f$
- $KE_f + PE_f = KE_o + Pe_o$
- We define the mechanical energy of a body as
  - $E = PE + KE$
  - E is conserved for conservative forces (i.e. $E_f = E_o$)

Gravity Rail



$$E = KE + PE$$

$$= PE_{max} \text{ @ top}$$

$$= KE_{max} + PE_{min}$$
@ bottom