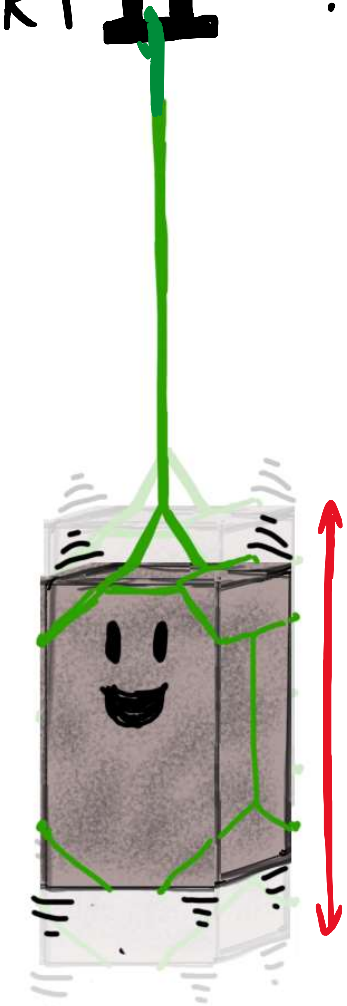
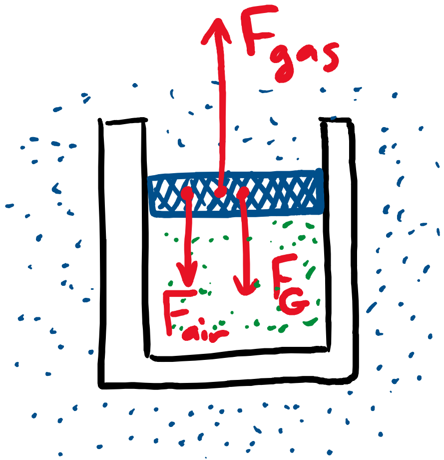
Physics 157 Part II : Oscillations & Waves

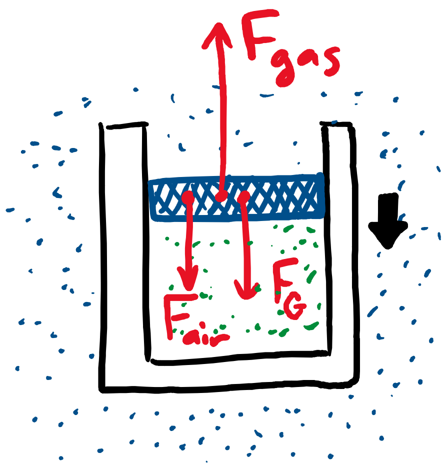


MECHANICAL EQUILIBRIUM: occurs when forces (and torques) on each part of the system add to zero



example: $\vec{F}_{gas} + \vec{F}_{gravity} + \vec{F}_{air} = 0$

- piston is in equilibrium



What happens to the forces if we move the piston downward a little (assume the cylinder is insulated)?

A) $|F_{gas}|$ increases a little while the other forces remain the same.

B) $|F_{gas}|$ increases a little and $|F_{air}|$ increases to compensate.

C) $|F_{gas}|$ decreases a little and the other forces remain the same.

D) $|F_{gas}|$ decreases a little and $|F_{air}|$ decreases to compensate.

E) Nothing: all forces remain the same.

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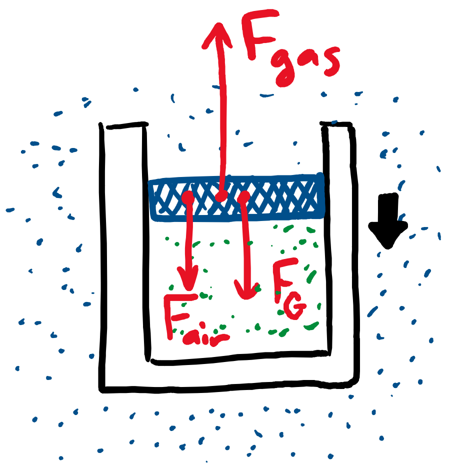

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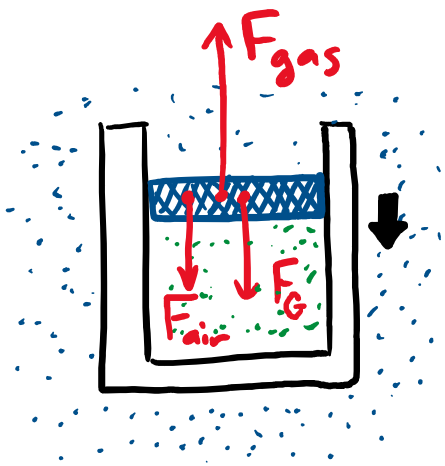
Adiabatic compression:
$PV^{\gamma} = \text{const}$
$V\downarrow$ so $P\uparrow$
so $F_{air}\uparrow$

gravity & outside air pressure remain constant



What happens to the forces if we move the piston upward a little (assume the cylinder is insulated)?

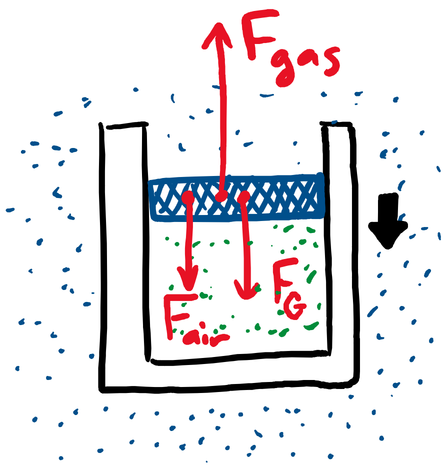
A) $|F_{gas}|$ increases a little while the other forces remain the same.

B) $|F_{gas}|$ increases a little and $|F_{air}|$ increases to compensate.

C) $|F_{gas}|$ decreases a little and the other forces remain the same.

D) $|F_{gas}|$ decreases a little and $|F_{air}|$ decreases to compensate.

E) Nothing: all forces remain the same.



Adiabatic expansion

$P\downarrow$ so $|F_{gas}|\downarrow$

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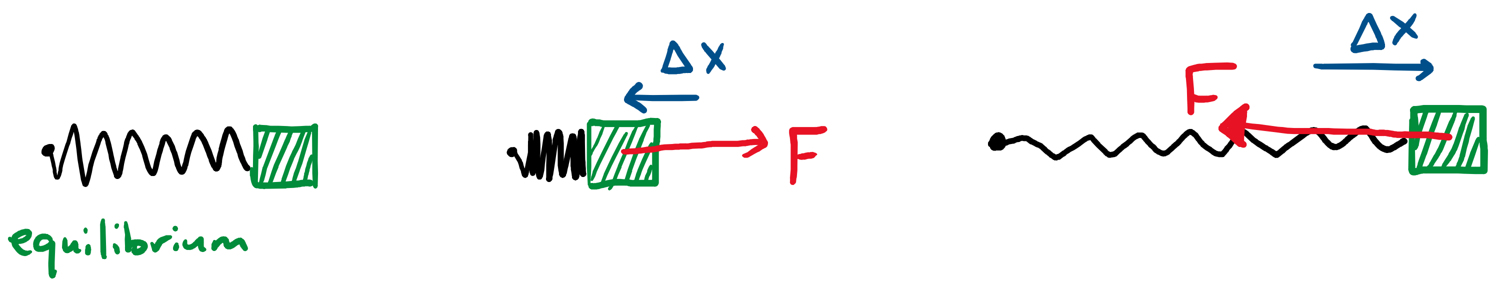
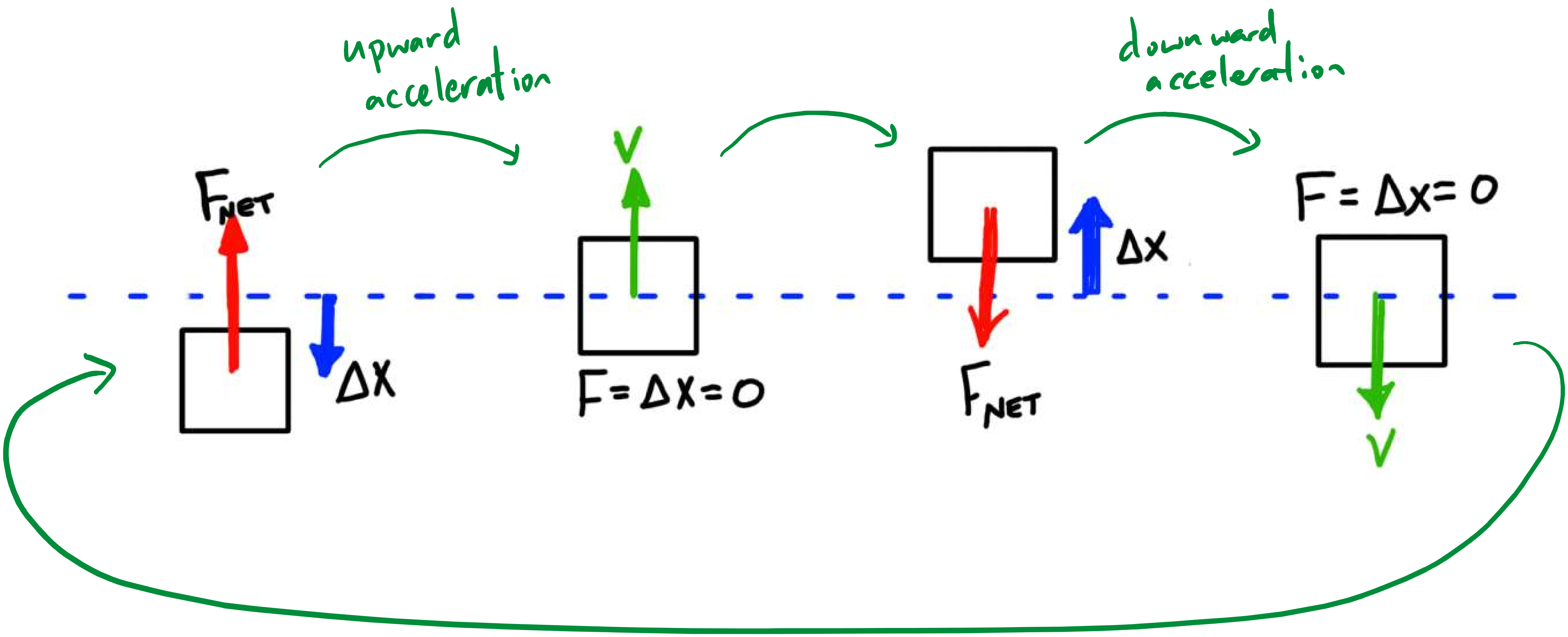
RESTORING FORCES: For a STABLE equilibrium configuration, a displacement in one direction leads to a net force in the other direction.

e.g.



This leads to OSCILLATIONS = periodic motion

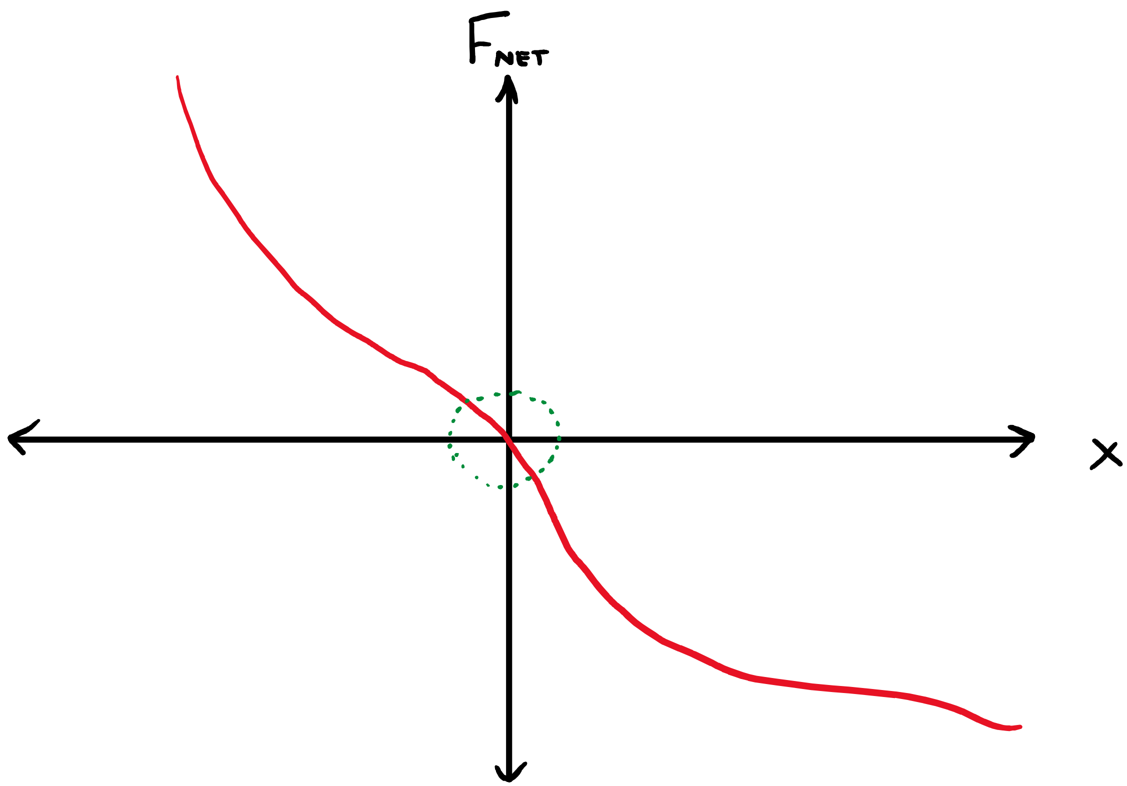


Demo: weight on a spring

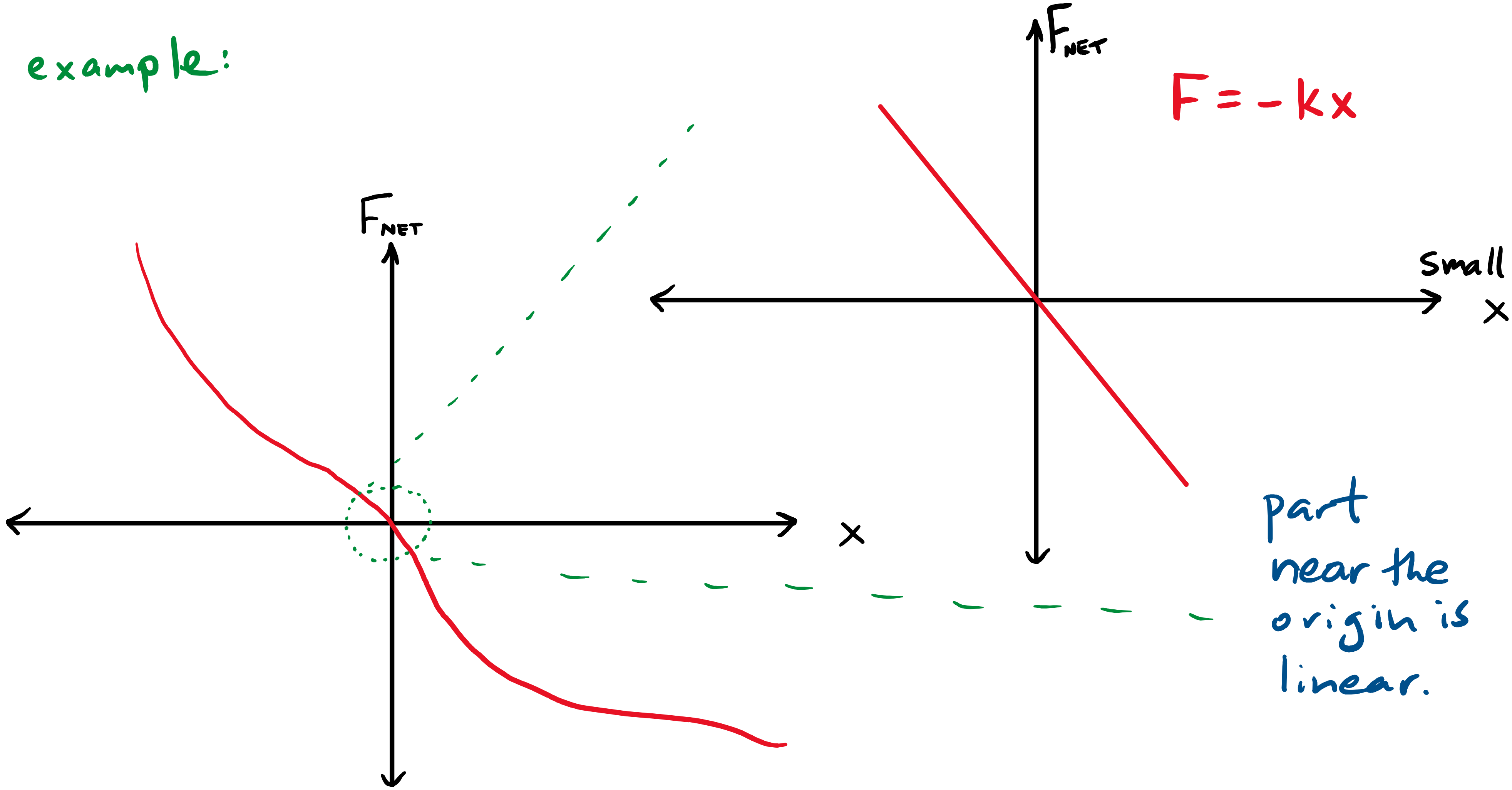
Exercise: for an object in a stable equilibrium configuration, draw some possible graphs of the net force on this object as a function of the displacement x.

EXTRA: what does your graph look like if you zoom in to the region of small Δx. Can you write down an equation that describes F vs Δx in this region?

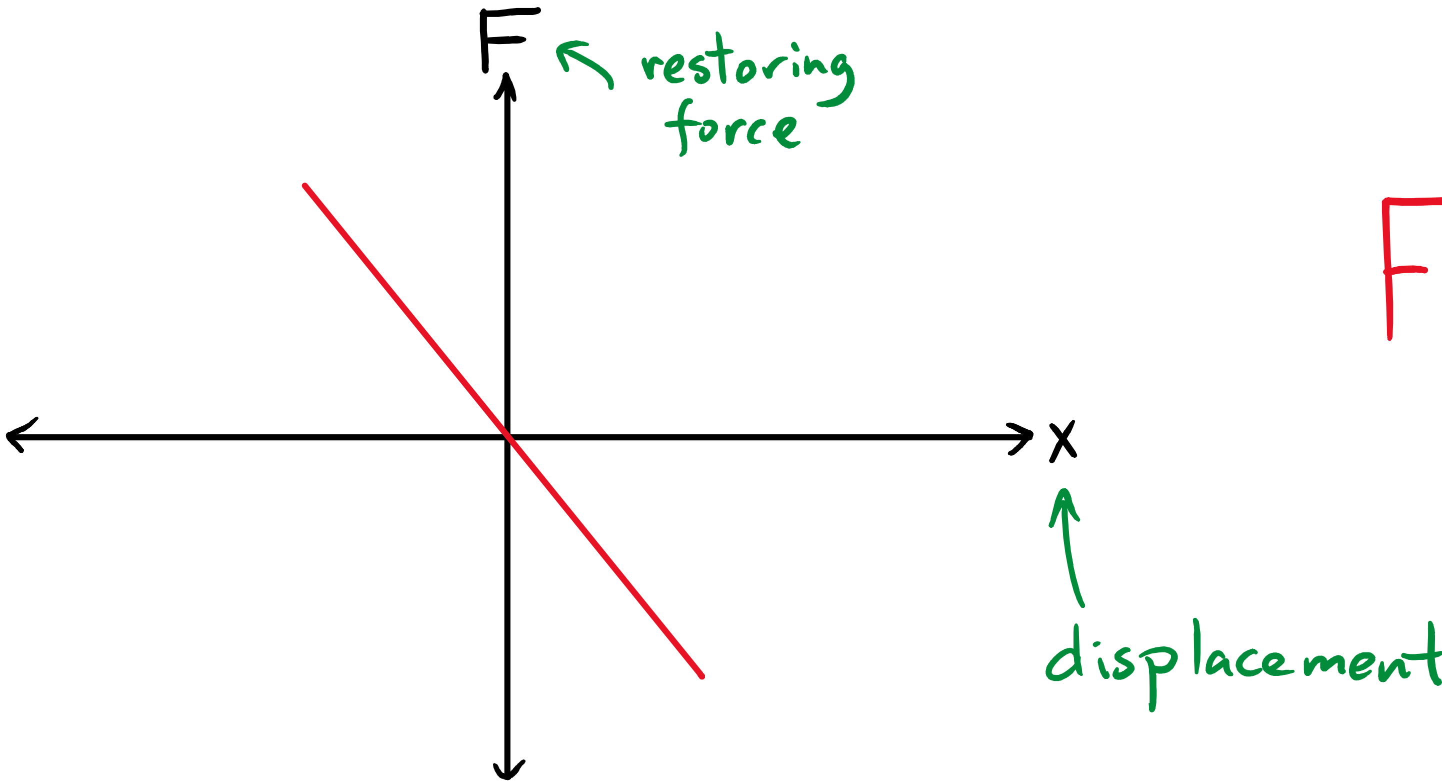
example:



example:



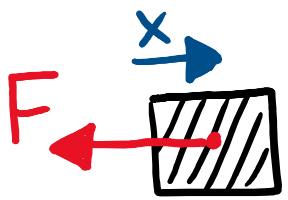
HOOKE'S LAW: Applies to almost any system perturbed a small amount from stable equilibrium



$$F = -kx$$

exact for "ideal spring"

Oscillations with Hooke's Law:



$F = -kx$

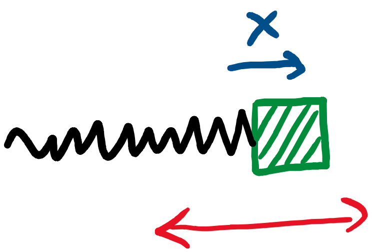
$F = ma$ gives $-kx = ma$

- solve for $a = \frac{d^2x}{dt^2}$

$$\frac{d^2x}{dt^2} = -\frac{k}{m}x$$

Math fact: most general function with this property is $x(t) = A\cos(\omega t + \phi)$

Simple Harmonic Motion



$$x(t) = A\cos(\omega t + \phi)$$

- A — Amplitude
- ω — angular frequency
- ϕ — phase