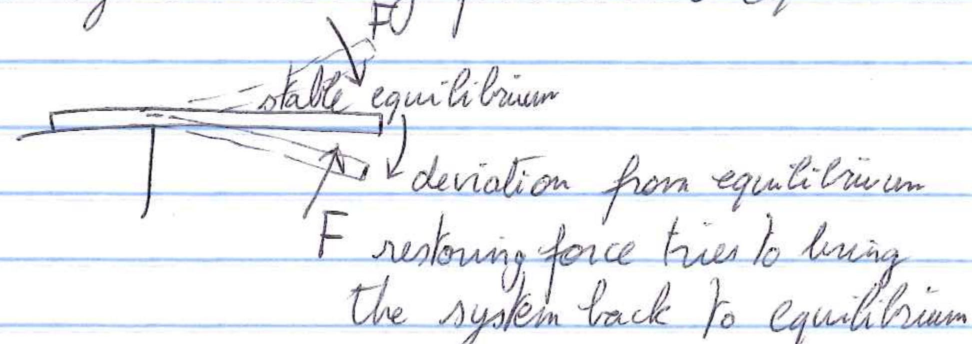
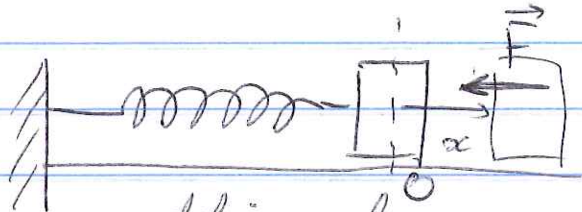
What is periodic motion? - grandfather clock, pendulum
- guitar string, water ~~waves~~ waves
- sound, light, AC electricity
- vibrations of molecules
- earthquakes waves propagate through the earth
- variations in brightness of stars

Simplest description of periodic phenomena and oscillations:
caused by some restoring force around equilibrium

Example:

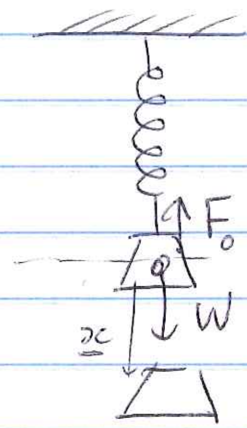


Features: - stable equilibrium
- restoring force
- system builds up kinetic energy and overshoots
. now the deviation is on the opposite side



restoring force $\vec{F} = -kx$

equilibrium when spring is not extended



equilibrium when $F_0 = -k\Delta L = W$

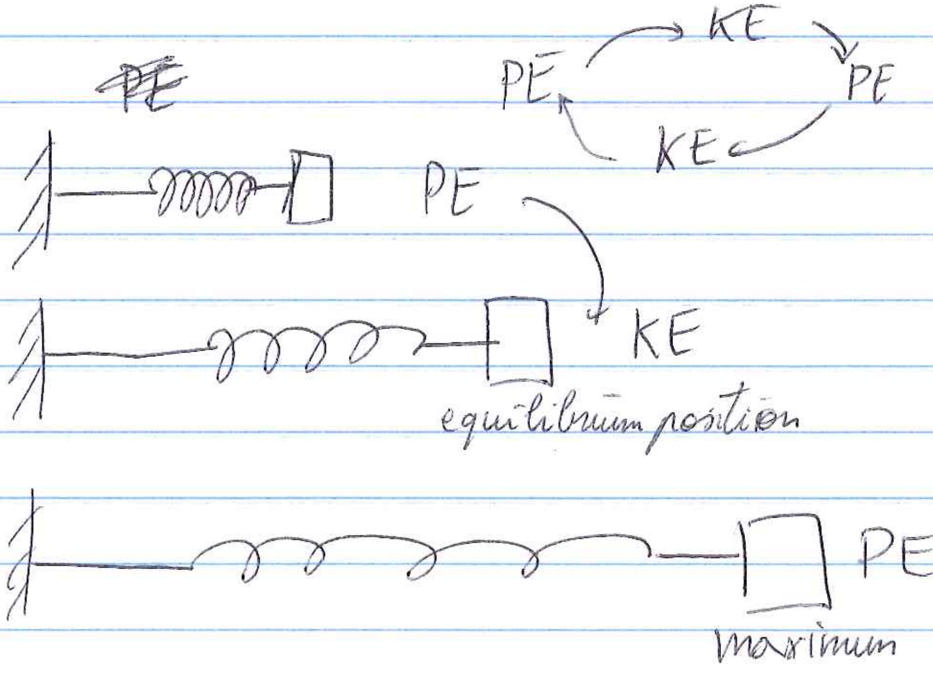
$F = -kx$ restoring

Hooke's law : $F = -k\Delta L \rightarrow$ equilibrium at $x = 0$

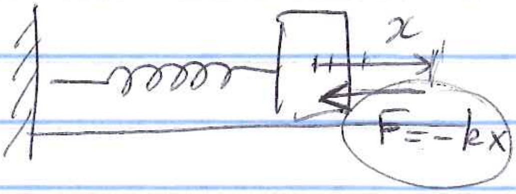
a maximum $\longrightarrow$ $F = ma$ $\rightarrow$ F maximum

$F = -kx$ $\rightarrow$ when x is maximum

* Energy

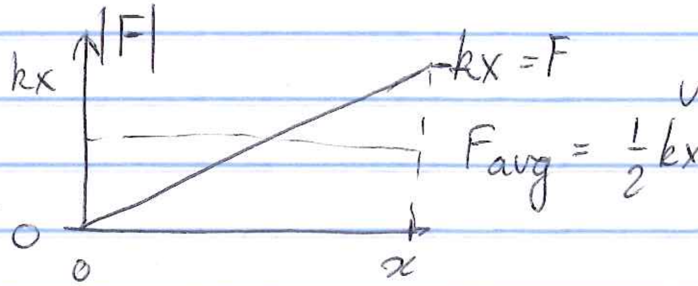


PE for spring $= \frac{1}{2} k x^2$



naive derivation:

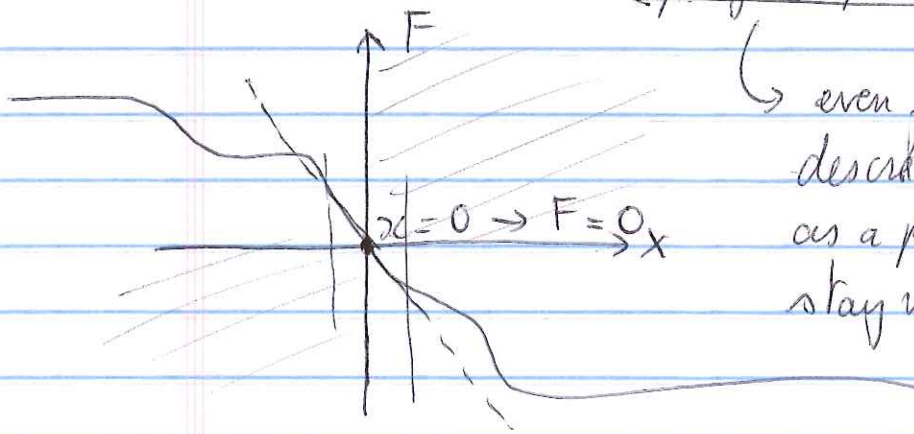
$$W = F \cdot d \cos\theta \quad , \theta = 180^\circ$$
$$= -kx \cdot x \cos 180^\circ$$
$$= kx^2$$



improved derivation:

$$W = F_{avg} \cdot d \cos\theta$$
$$= -\frac{1}{2} kx \cdot x \cdot \cos 180^\circ$$
$$\underline{PE_k = \frac{1}{2} kx^2}$$

* What about imperfect springs? $F \neq -kx$



↳ even for imperfect springs, we can describe them using $F = -kx$ as a perfect spring as long as we stay within a small enough region around the equilibrium

* Frequency and period

T = period = time for one oscillation (units of s)

$f = \frac{1}{T}$ = frequence = how many oscillations in 1 second (units: $s^{-1} = Hz$)

piano playing A : $f = 440Hz \rightarrow T = \frac{1}{f} = 2.27ms$

WCWM $f = 90.3$ MHz $\rightarrow T = \frac{1}{f} = 1.1 \times 10^{-8}$ s $= 11$ ns

* Simple harmonic oscillator (SHM)
  ↳ spring that satisfies $F = -kx$ everywhere

In SHM : f (and T) are independent of the amplitude

A = amplitude = maximum displacement from equilibrium

What does T, f depend on? m, k

m : units kg

k : units $N/m = \frac{kg}{s^2}$

T : units s $\rightarrow T \sim \sqrt{\frac{m}{k}}$

$$T = 2\pi\sqrt{\frac{m}{k}} \rightarrow f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \rightarrow \omega = 2\pi f = \sqrt{\frac{k}{m}}$$

* How does x change over time?

$$x = A\cos(\omega t) = A\cos(2\pi f)t$$
$$= A\cos\left(2\pi \frac{t}{T}\right)$$