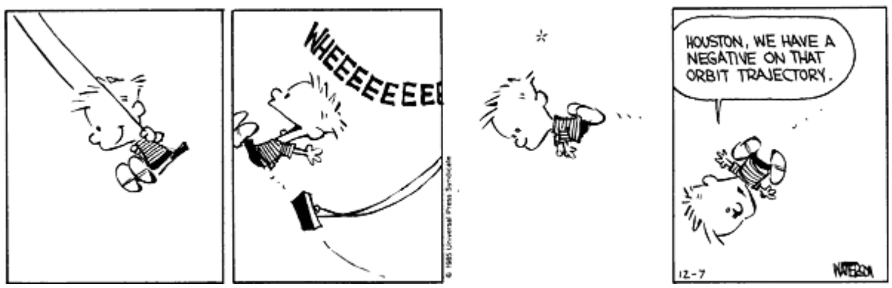
March 29, 2013 Physics 132 Prof. E. F. Redish

- **Theme Music:** **Benny Goodman**

  Swing, Swing, Swing

- **Cartoon:** **Bill Watterson**

  Calvin & Hobbes



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Mathematical structure

- Express $a = F^{net}/m$ in terms of derivatives.

$$\frac{d^2x}{dt^2} = -\omega_0^2 x$$

- Except for the constant, this is like having a functions that is its own second derivative.

$$\frac{d^2 f}{dt^2} = -f$$

- In calculus, we learn that sin(t) and cos(t) work like this. How about: $\boxed{x = \cos t}$?

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Interpreting the Result

- We can easily take the derivatives to show that our solution $x(t) = A\cos(\omega_0 t)$ satisfies the N2 equations
- What do the various terms mean?
  - A is the maximum displacement — the *amplitude*.
  - What is ω_0? If T is the *period* (how long it takes to go through a full oscillation) then

$$\omega_0 t : 0 \rightarrow 2\pi$$
$$t \quad : 0 \rightarrow T$$
$$\omega_0 T = 2\pi \quad \Rightarrow \quad \omega_0 = \frac{2\pi}{T}$$

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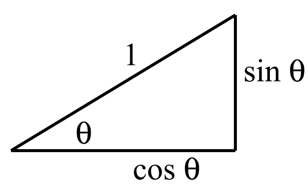
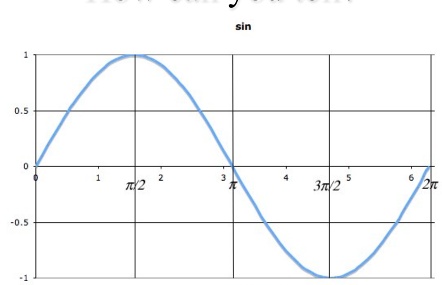
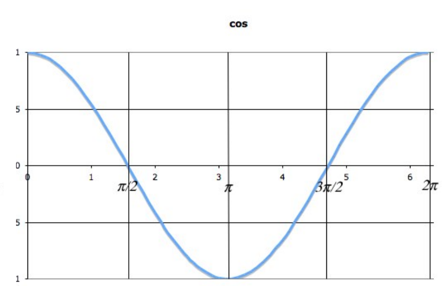
Graphs: sin(θ) vs cos(θ)

- Which is which? How can you tell?
- The two functions sin and cos are derivatives of each other (slopes), but one has a minus sign. Which one? How can you tell?





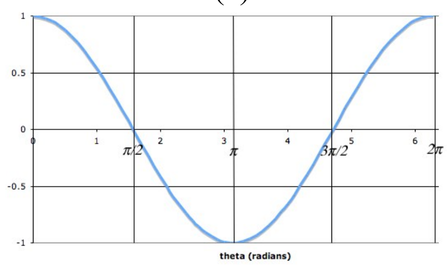


Graphs: sin(θ) vs sin(ω_0t)

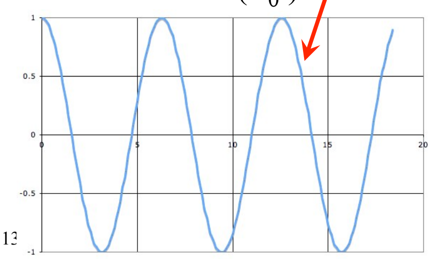
- For angles, θ = 0 and θ = 2π are the same so you only get one cycle.
- For time, t can go on forever so the cycles repeat.

What does changing ω_0 do to this graph?

cos(θ)

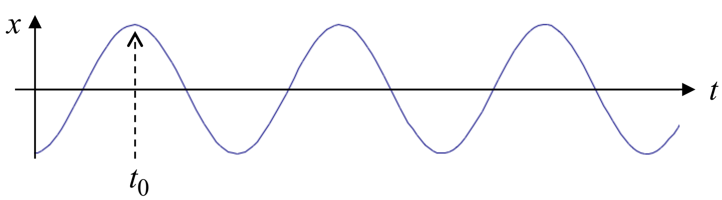


cos($\omega_0 t$)



Interpreting the Result

- What about the starting point?
  Using cos means you always start at a peak when t = 0. That might not always be true.



$$x(t) = A\cos(\omega_0(t - t_0))$$
$$= A\cos(\omega_0 t - \omega_0 t_0) = A\cos(\omega_0 t - \phi)$$

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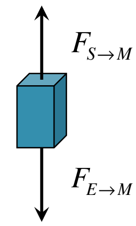
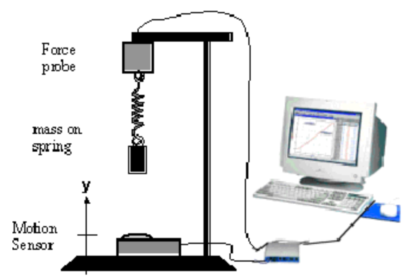
Summary with Equations: Mass on a spring



Measured from where?

$$a = \frac{1}{m}F^{net} \qquad F^{net} = -kx$$

$$a = -\omega_0^2 x \qquad \omega_0^2 = \frac{k}{m}$$



$$x(t) = A\cos(\omega_0 t + \phi)$$

$$\omega_0 = \frac{2\pi}{T}$$

Interpret!

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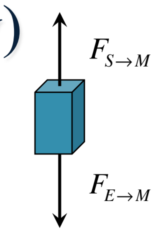
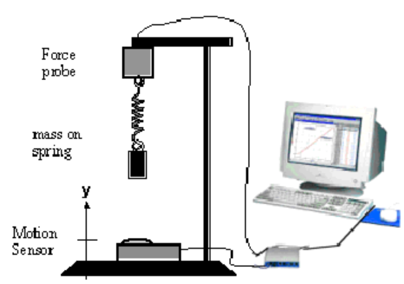
Summary with Equations: Mass on a spring (Energy)



Measured from where?

$$E = \tfrac{1}{2}mv^2 + mgh + \tfrac{1}{2}k(\Delta l)^2$$

$$E_i = E_f$$



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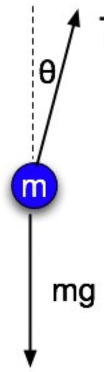
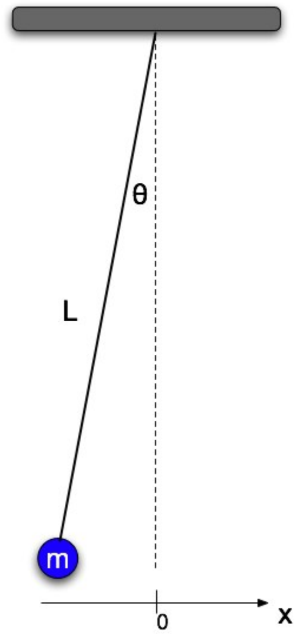
The Long Pendulum





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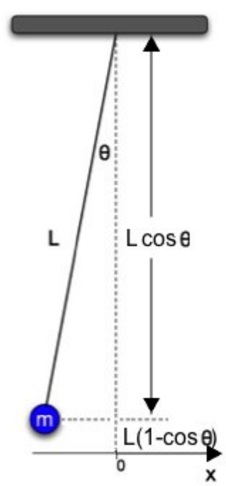
Pendulum motion energy

$$E_0 = \tfrac{1}{2}mv^2 + mgh = \tfrac{1}{2}mv^2 + mgL(1-\cos\theta)$$
$$\cos\theta \approx 1 - \tfrac{1}{2}\theta^2$$
$$E_0 \approx \tfrac{1}{2}mv^2 + \tfrac{1}{2}[mgL]\theta^2$$
$$\theta \approx \sin\theta = \frac{x}{L}$$
$$E_0 \approx \tfrac{1}{2}mv^2 + \tfrac{1}{2}kx^2 \qquad k = \frac{mg}{L}$$



Same as mass on a spring!
Just with a different $\omega_0^2 = k/m = g/L$

What's the period? Why doesn't it depend on m?

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