Simple Harmonic Motion

What do all *harmonic* oscillations have in common?

- A position of equilibrium
- A restoring force, which must be *linear*

  ($F = -kx$; F = mg is only linear for small angles: $\sin\theta = \theta = s/L$

  In this limit we have: $F = -ks$ with $k = mg/L$)
- Inertia
- The resistive forces are reasonably small

Simple Harmonic Motion

More tools:

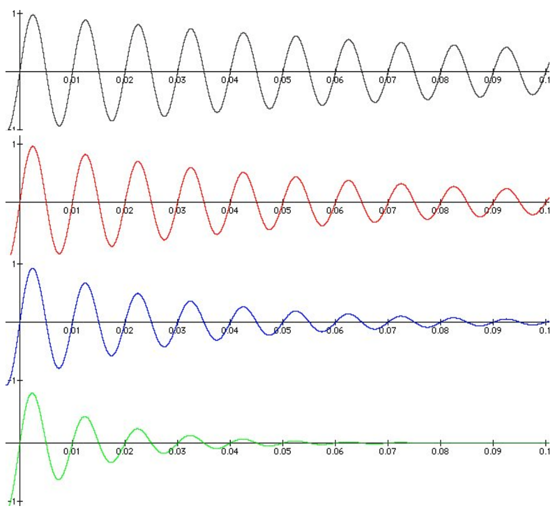
Position, velocity, acceleration

Energy

Damping

DC

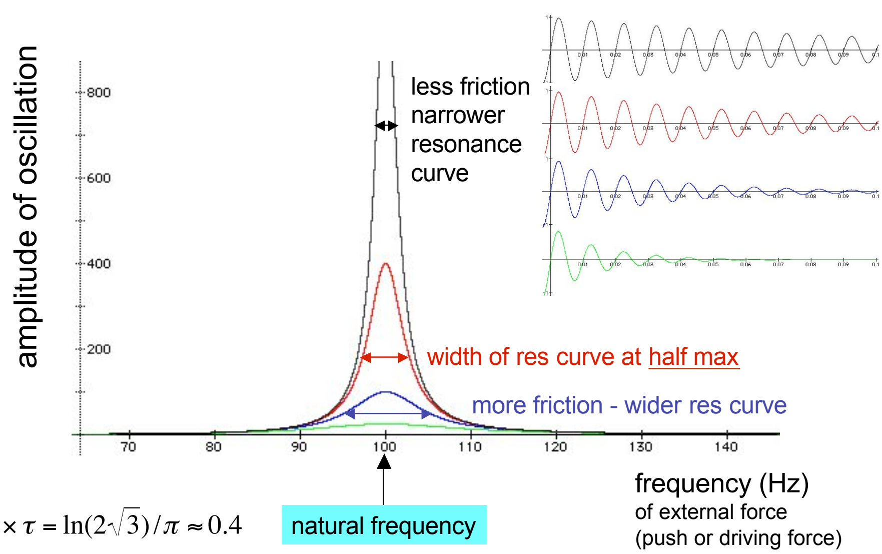
Damped oscillations of same system:



least friction
$\tau = 0.066$ sec

most friction
$\tau = 0.011$ sec

resonance curves for different amount of friction



$\Delta f \times \tau = \ln(2\sqrt{3})/\pi \approx 0.4$

width of resonance curve and damping time: inverse relation

Examples:

1. Sitar (Northern India) 7 strings + 11 sympathetic strings

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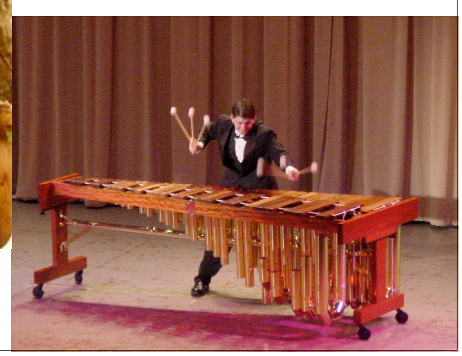

Examples:

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2. Marimba
3. Xylophone

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2. Marimba
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4. Soundboards of instruments (piano, guitar, etc.) avoid resonances

5. loudspeaker: flexible cardboard cone supported by a springy rim.

   It is supposed to respond almost uniformly over a wide frequency range

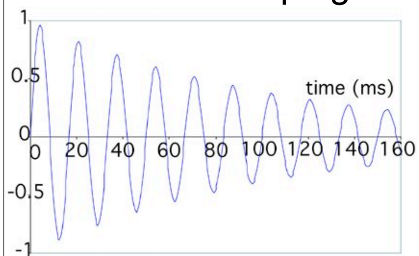
   thus: wide resonance curve and short damping time
   thus: large friction, → inefficient (e.g.100-Watt electrical output amplifier for 3 Watt sound output)
   tweeter + midrange + woofer to even out frequency response.

6. tone dialing: resonance circuits at phone center switchboard

demo
videos 4,5,6

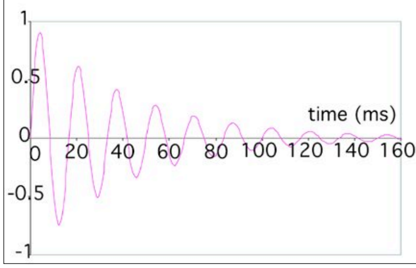
Simple Harmonic Motion

More tools: damping



large damping time constant τ
low friction coefficient b

$\tau = m/b$



small damping time constant τ
high friction coefficient b

DC

damped oscillations

A can of coke is attached to a spring and is displaced by hand.
$m = 0.25$ kg
$k = 25.0$ N/m.
The coke can is released, and it starts oscillating with an amplitude $A_o = 0.3$ m.

A damping force $\mathbf{F_x = -bv}$ acts on the can.
After it oscillates for 5.00 s, the amplitude of the motion has decreased to $A_1 = 0.1$ m.

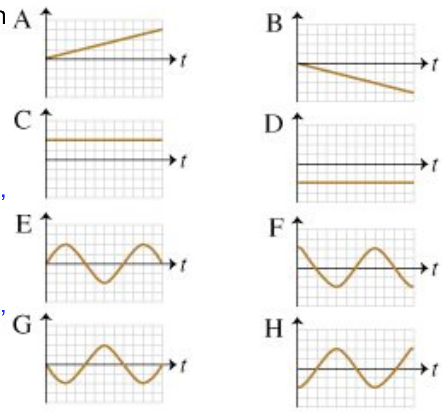
What is the magnitude of the damping coefficient b?

$b = 0.11$ kg/s

How damped is the system?
- Underdamped (multiple oscillations with an exponential decay in amplitude).
- Critically damped (simple decaying motion with at most one overshoot of the system's resting position).
- Overdamped (simple exponentially decaying motion, without *any* oscillations).

SHM kinematics

A simple pendulum is displaced to the left of its equilibrium position and released. Set the origin of the coordinate system at the equilibrium position of the pendulum, and let counterclockwise be the positive angular direction. Assume air resistance is negligible.



Beginning the instant the pendulum is released, select the graph that best matches the angular position vs. time graph for the pendulum.

H

Beginning the instant the pendulum is released, select the graph that best matches the angular velocity vs. time graph for the pendulum.

E

Beginning the instant the pendulum is released, select the graph that best matches the angular acceleration vs. time graph for the pendulum.

F