How was Midterm 2 for you?

A) *Way* too hard - no fair!

B) Hard, but fair

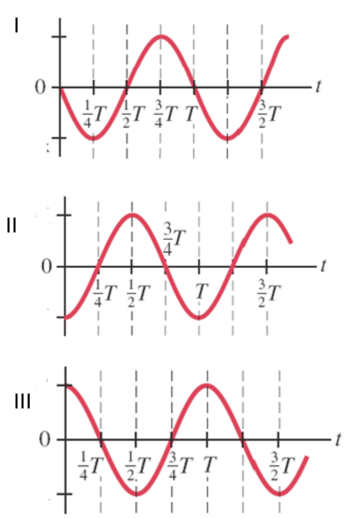
C) Seemed reasonable.

D) Easy/fair enough, thanks!

E) Almost too easy, really should make it harder next time!

Quick Review after the break

If a spring is pulled away its equilibrium point to x>0 and released from rest, the plots shown below correspond to



A) I: velocity, II:position, III:acceleration

B) I: position, II:velocity, III:acceleration

C) I: acceleration, II:velocity, III:position

D) I: velocity, II:acceleration, III:position

E) I do not have enough information

Important concepts

Angular frequency $\omega = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$

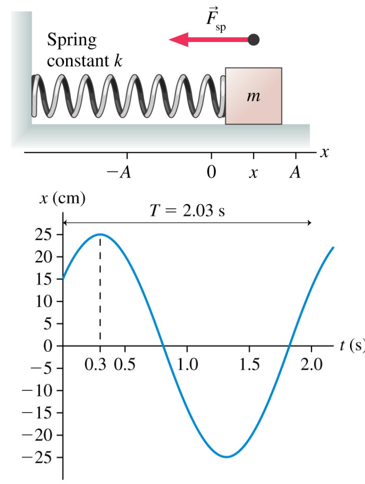
Frequency: $f = \frac{1}{T}$

Position: $x(t) = A\cos(\omega t + \delta)$

Velocity: $v(t) = -A\omega\sin(\omega t + \delta)$

Acceleration: $a(t) = -\omega^2 x(t)$

Energy: $E = \frac{mv^2}{2} + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$



No friction implies conservation of mechanical energy

Damped Oscillations

In most physical situations, there are nonconservative forces of some sort, which will tend to decrease the amplitude of the oscillation. In many cases (e.g. viscous flow) the damping force is proportional to the speed:

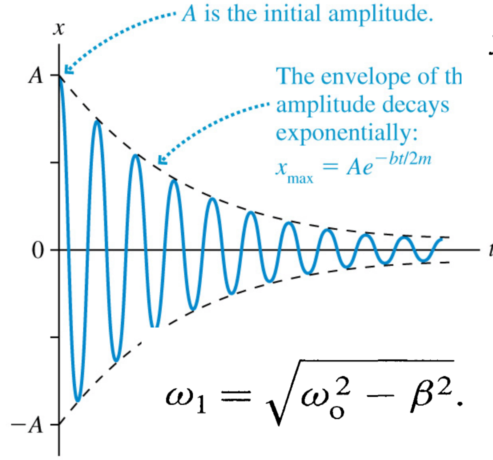
$$F_{drag} = -bv \quad 2\beta = b/m$$

$$F = m\ddot{x} = -kx - b\dot{x}$$

$$\ddot{x} + 2\beta\dot{x} + \omega_0{}^2 x = 0$$

Underdamped Oscillations

An *underdamped oscillation* *with b<w$_0$*:



$$x(t) = Ae^{-\beta t}\cos(\omega_1 t - \delta).$$

$$\beta < \omega_o$$

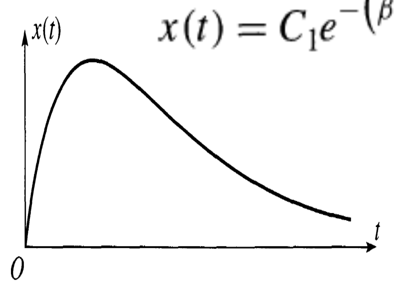
$$\omega_1 = \sqrt{\omega_o^2 - \beta^2}.$$

Note that damping ***reduces*** the oscillation frequency.

Overdamped Oscillations

An *overdamped oscillation* *with b>w$_0$*:

$$x(t) = C_1 e^{-\left(\beta - \sqrt{\beta^2 - \omega_o^2}\right)t} + C_2 e^{-\left(\beta + \sqrt{\beta^2 - \omega_o^2}\right)t}.$$



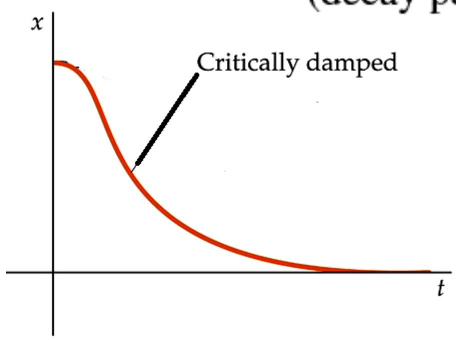
$$(\text{decay parameter}) = \beta - \sqrt{\beta^2 - \omega_o^2}$$

Critically damped Oscillations

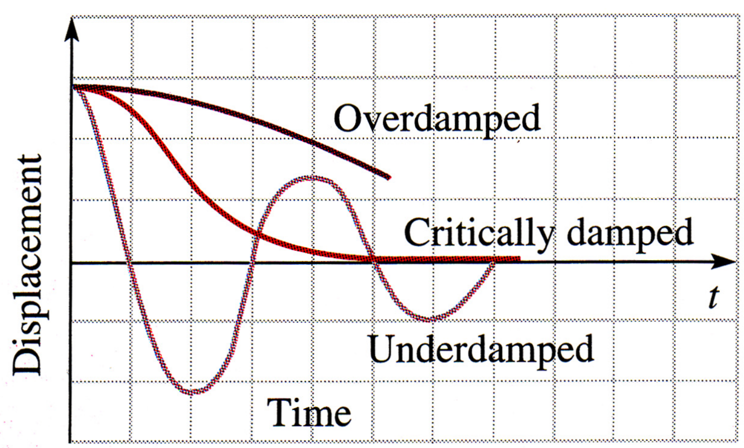
A critically damped *oscillation* *with b=w$_0$*:

$$x(t) = C_1 e^{-\beta t} + C_2 t\, e^{-\beta t}.$$

$$(\text{decay parameter}) = \beta = \omega_0$$

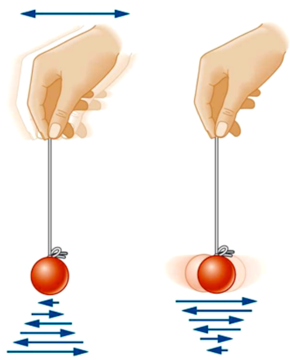


Damped oscillations



This class

Driven Oscillations & Resonance



1. Particular and homogeneous solution
2. Response to periodic driving forces: amplitude and phase.
3. Tutorial
4. Resonance: concept, Q factor

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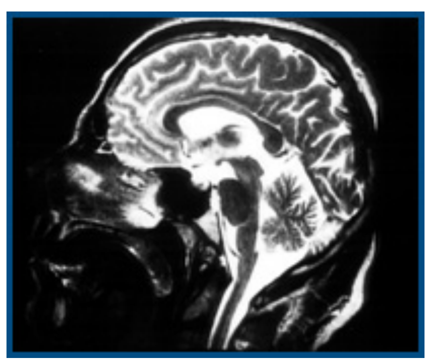
Driven oscillators and Resonance: phenomena occur widely in natural and in technological applications:

Emission & absorption of light
Lasers
Tuning of radio and television sets
Mobile phones
Microwave communications
Machine, building and bridge design
Musical instruments
Medicine
– nuclear magnetic resonance
  magnetic resonance imaging
– x-rays
– hearing



Nuclear magnetic resonance scan

CP 465

What is the particular solution to the equation
$y''+4y'-12y=5$?

A) $y=e^{5t}$
B) $y=-5/12$
C) $y=-a\ 5/12$, a determined by initial conditions
D) $y= a\ e^{2t} + b\ e^{-6t} + 5$

Consider the following equation

$$x''+16x=9\sin(5t),\quad x(0)=0,\ x'(0)=0$$

The solution is given by

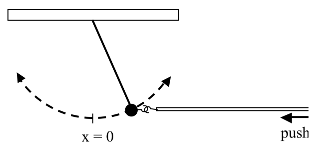
A. $x(t)=c_1\cos[4t]+c_2\sin[4t]-\sin(5t)$

B. $x(t)=5/4\sin[4t]-\sin(5t)$

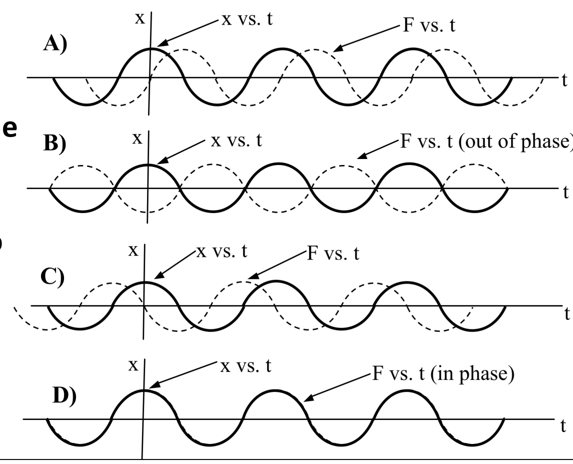
C. $x(t)=\cos[4t]-\cos(5t)$

D. I do not know

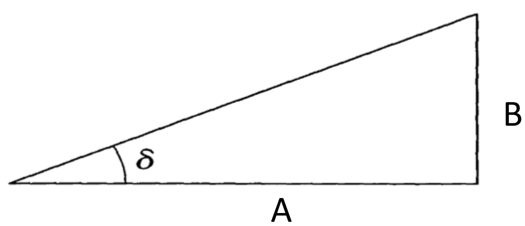
A person is pushing and pulling on a pendulum with a long rod. Rightward is the positive direction for both the force on the pendulum and the position x of the pendulum mass



To maximize the amplitude of the pendulum, how should the phase of the driving force be related to the phase of the position of the pendulum?



The phase angle d in this triangle is



A. $\delta = \arctan\left(\frac{B}{A}\right)$ B. $\delta = arc\cot\left(\frac{A}{B}\right)$

C. $\delta = \arctan\left(\frac{A}{B}\right)$ D. More than one is correct

D. None of these are correct