CHM 305 The Quantum World
Lecture 2: Classical Waves

Reading: McQuarrie Chap. 2

Big takeaways from last class?

Classical physics fails to predict some behaviors of light (blackbody radiation, photoelectric effect)

Light has a discrete energy determined by its frequency ($E = hv$)

Light can be described as being made up of individual "photon" particles

Particles have a wavelength given by deBroglie's expression ($\lambda = h/p$)

Particles can act like waves, e.g. interfere and diffract

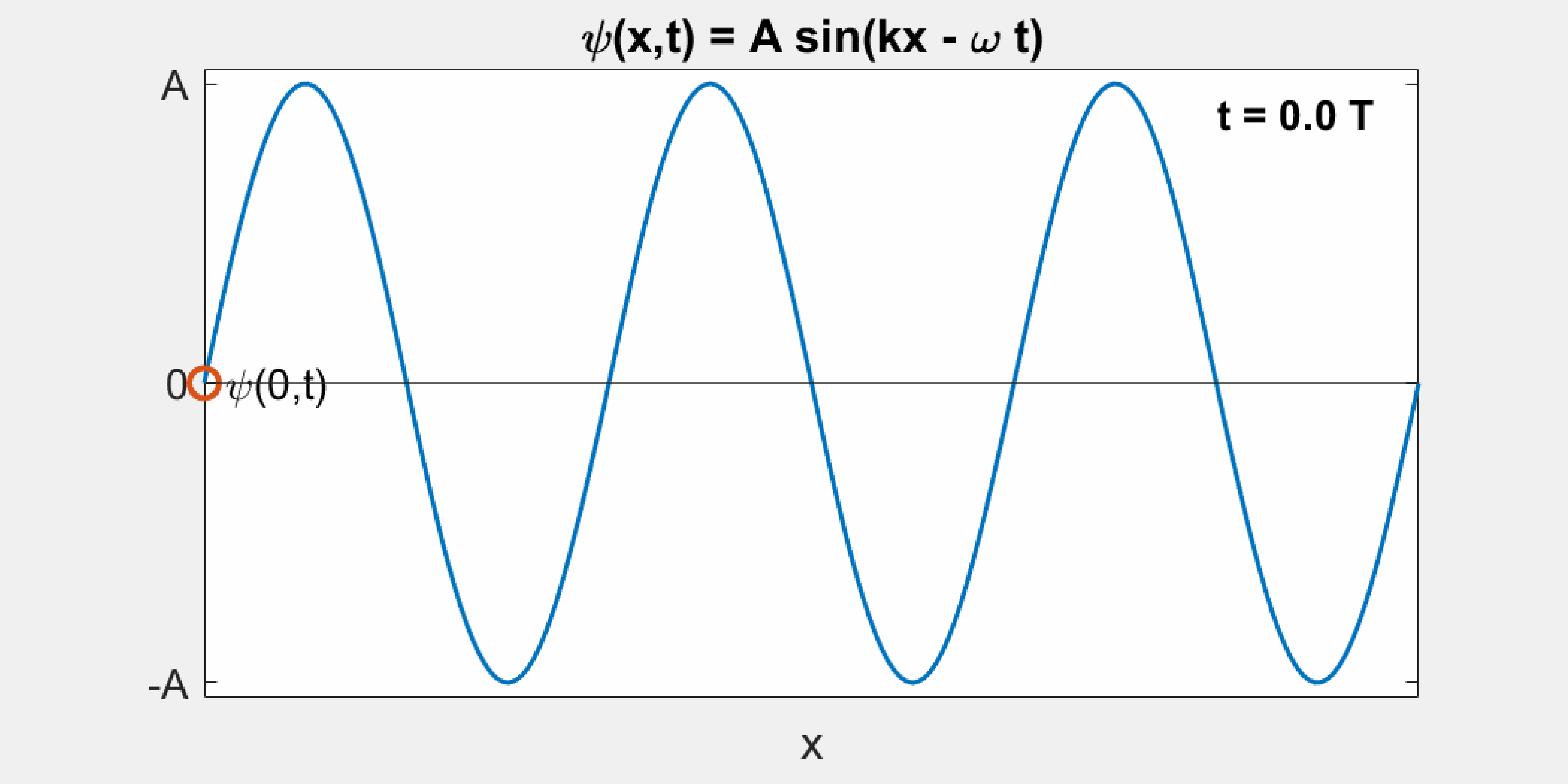
Quantum mechanics and classical physics are two regimes of the same set of universal physical laws

Quantum objects are described by wavefunctions that capture their probability distribution

Road map for today's lecture

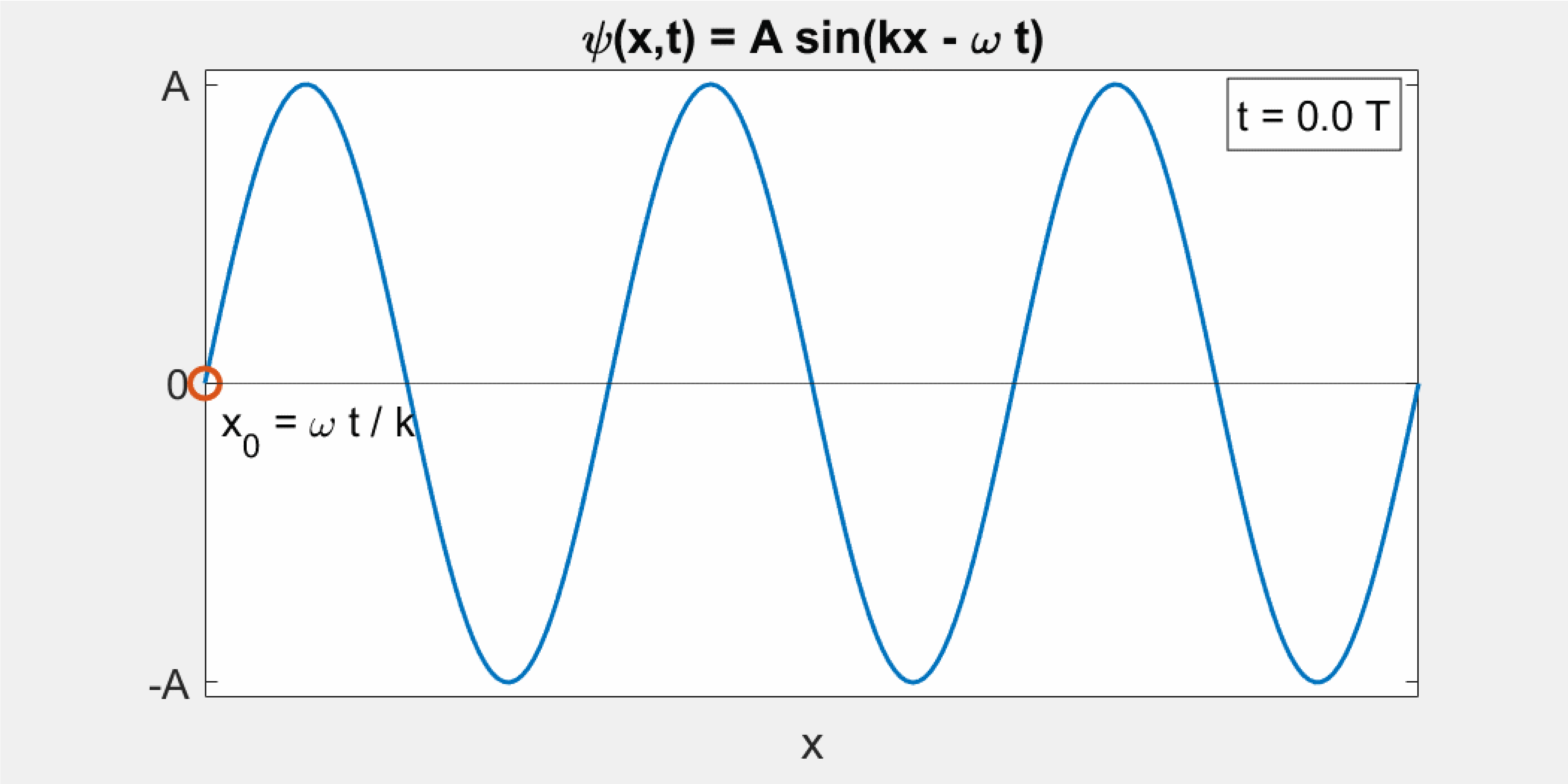
- Describe the evolution of classical waves in space and time using their ***wavefunction***
- Demonstrate how a classical wave obeys a differential equation called the ***wave equation***
- Show how the solutions to the wave equation with ***boundary conditions*** give us a set of standing wave solutions
- Standing waves will be a nice analogy for solutions to Schrödinger's quantum wave equation

A traveling wave oscillates in both time and space



Link to GIF: https://www.dropbox.com/scl/fi/2qs6rz4jej5ql0b3ycbfq/traveling_wave_origin.gif?rlkey=o5qvcxxjx6l2bdjklinyadz3u&dl=0

Finding the velocity of a traveling wave



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Practice problem: Simple differential equations

Consider the differential equation: $$\frac{d^2y}{dx^2} + 2\frac{dy}{dx} + 10y = 0$$

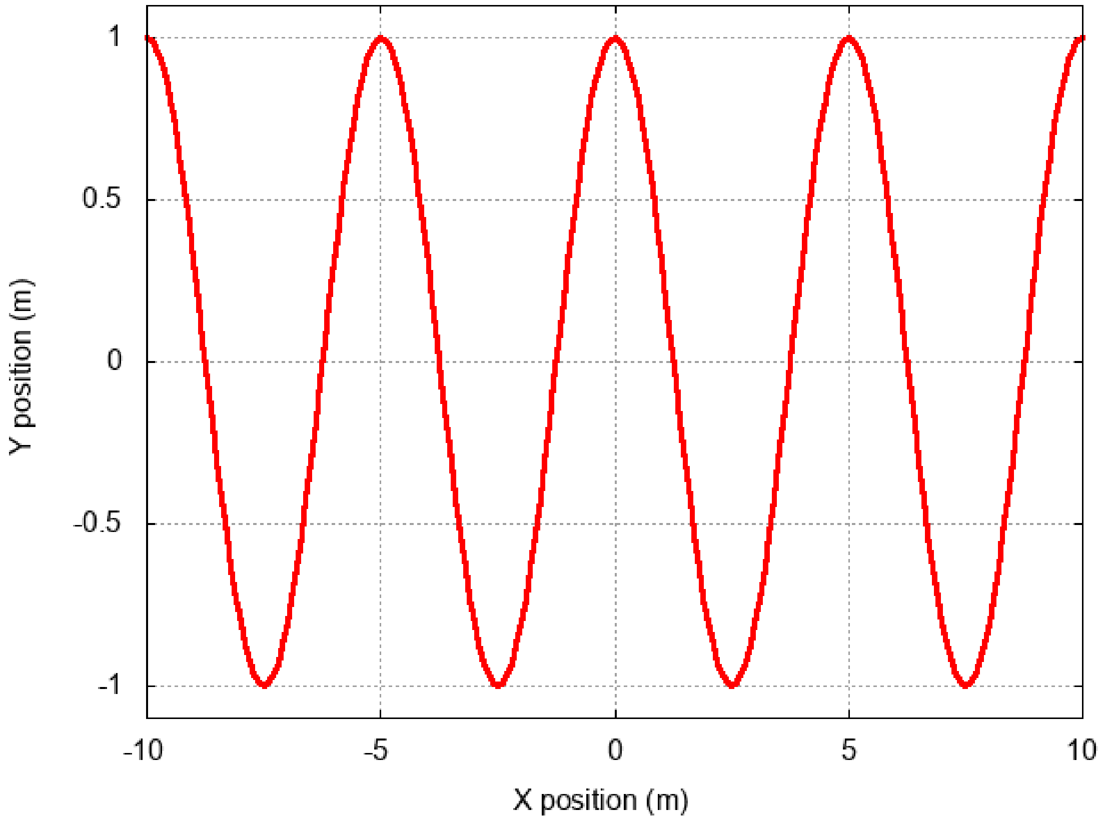
We will make the guess that: $$y = e^{\alpha x}$$

Solve for α . *Hint: it's complex!*

Can you sketch or describe conceptually how this solution behaves?

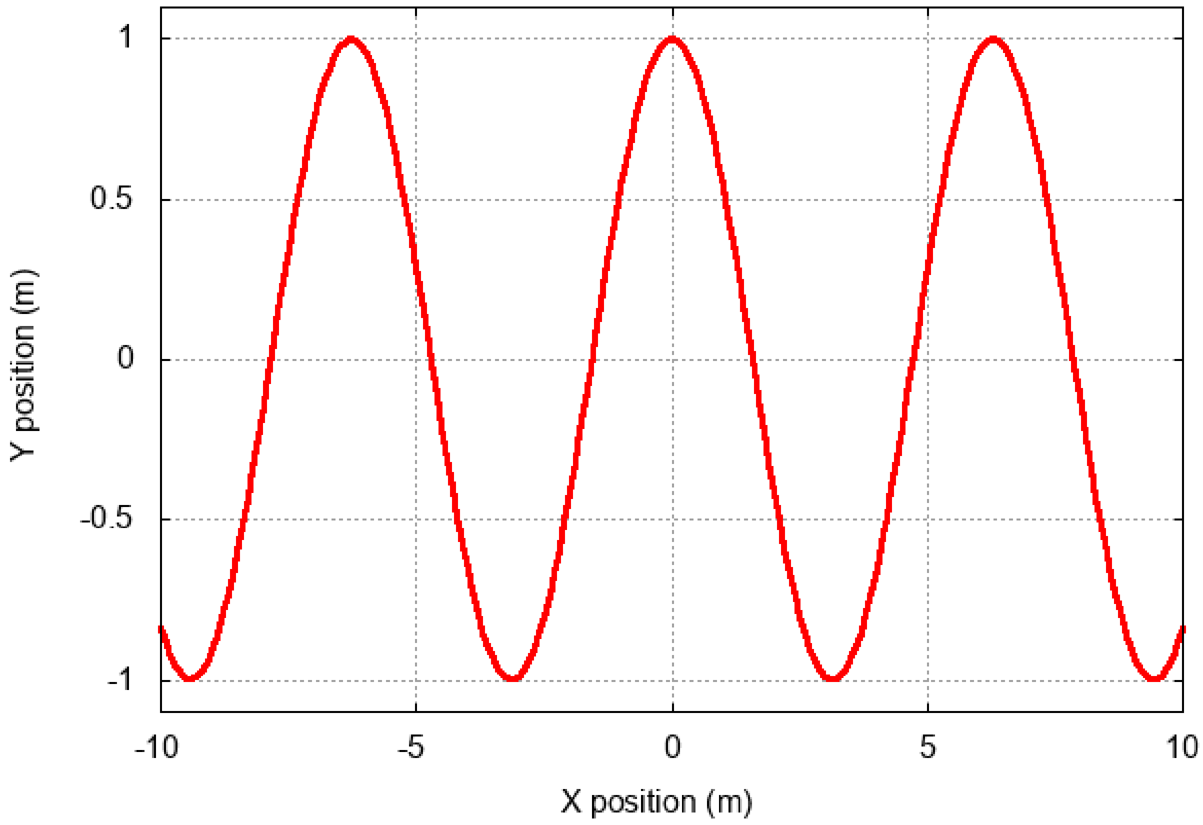
Traveling vs. standing waves

Traveling



http://spiff.rit.edu/classes/phys283/lectures/travel/travel_a.gif

Standing

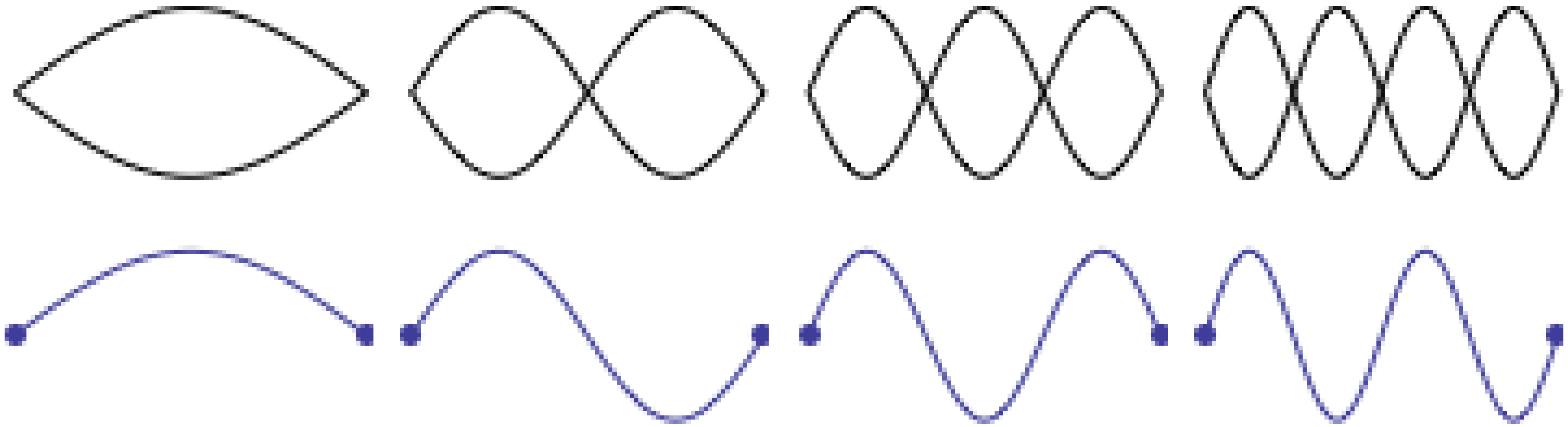


http://spiff.rit.edu/classes/phys283/lectures/travel/standing_a.gif

Standing wave normal modes:

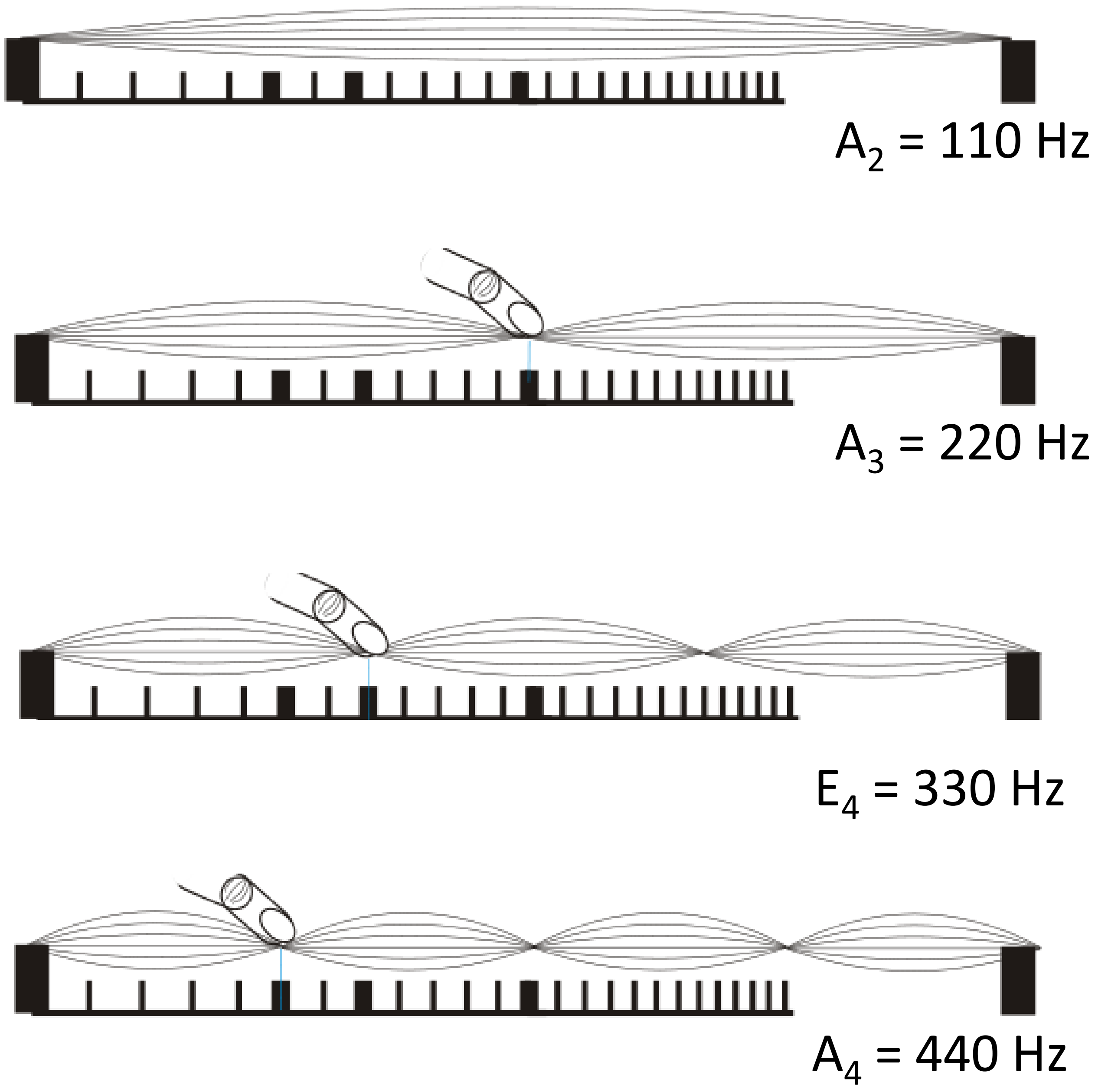
faster oscillations in both time and space as *n* increases

$n = 1$	$n = 2$	$n = 3$	$n = 4$
"first harmonic"	"second harmonic"	"third harmonic"	"fourth harmonic"



Gif source: https://www.acs.psu.edu/drussell/Demos/Pluck-Fourier/Pluck-Fourier.html

$X(x) =$	$\sin\left(\frac{\pi}{L}x\right)$	$\sin\left(\frac{2\pi}{L}x\right)$	$\sin\left(\frac{3\pi}{L}x\right)$	$\sin\left(\frac{4\pi}{L}x\right)$
$T(t) =$	$\sin(\omega_1 t + \phi_1)$	$\sin(\omega_2 t + \phi_2)$	$\sin(\omega_3 t + \phi_3)$	$\sin(\omega_4 t + \phi_4)$
	$\omega_1 = \frac{\pi v}{L}$	$\omega_2 = 2\omega_1$	$\omega_2 = 3\omega_1$	$\omega_2 = 4\omega_1$


A_2 = 110 Hz
A_3 = 220 Hz
E_4 = 330 Hz
A_4 = 440 Hz

Superpositions (or “chords”) also satisfy the wave eqn.

Link to GIF: https://www.dropbox.com/scl/fi/1ag9gnirg2tkeh1xc93ng/chords.gif?rlkey=lbi53pvi1qb4jcxnmt9glfvzh&dl=0