Physics 211

Sections 1 & 70
Dr. Geoffrey Lovelace
Fall 2012
Lecture 26 (12/11/12)

Lecture 26 outline

- Announcements
- Simple harmonic motion (SHM) wrapup
  - Equations of motion
  - Damped harmonic motion
- Wave motion
  - Definitions
  - Examples
  - Interference
  - Reflection, dispersion, diffraction
- Student Opinion Questionnaires (SOQs)
- Class participation (including followup)

Announcements

- Homework #11: due Thursday, 12/13 at 11:59PM
- Office hours: 4PM-5PM today
  - McCarthy Hall room 601B
- Final exam December 20, 9:30AM-11:20AM
  - Skip the final? See me in office hours!
  - Emphasize material since Exam #3 (cumulative)
- Today: Student Opinion Questionnaire (SOQ)

Today

Date	Event
Nov 15	**Exam 3**
Nov 20	*Fall Recess — No class*
Nov 22	*Fall Recess — No class*
Nov 27	Rigid body rotation, torque
Nov 29	Rotational dynamics, rotational energy
Dec 4	Angular momentum, rigid body wrap-up *HW #10 due*
Dec 6	Harmonic motion
Dec 11	Harmonic motion & waves
Dec 13	Gravitational waves, harmonic motion, black holes, *HW #11 due*
Dec 20	**Final exam 9:30AM–11:20AM**

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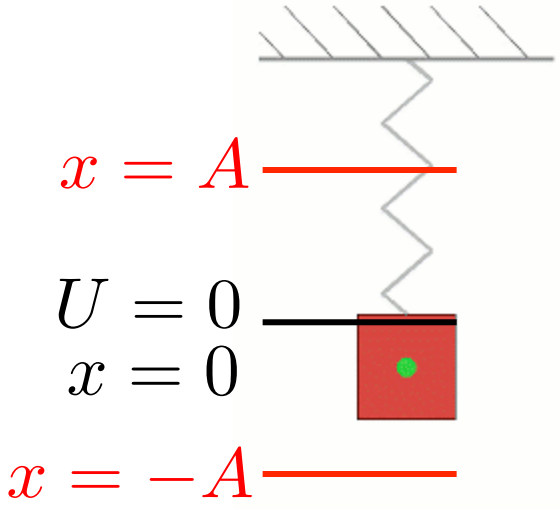
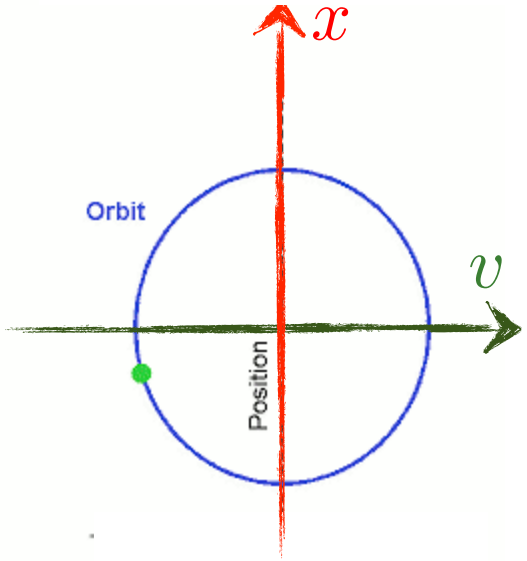
Mass *m* on a spring *k*

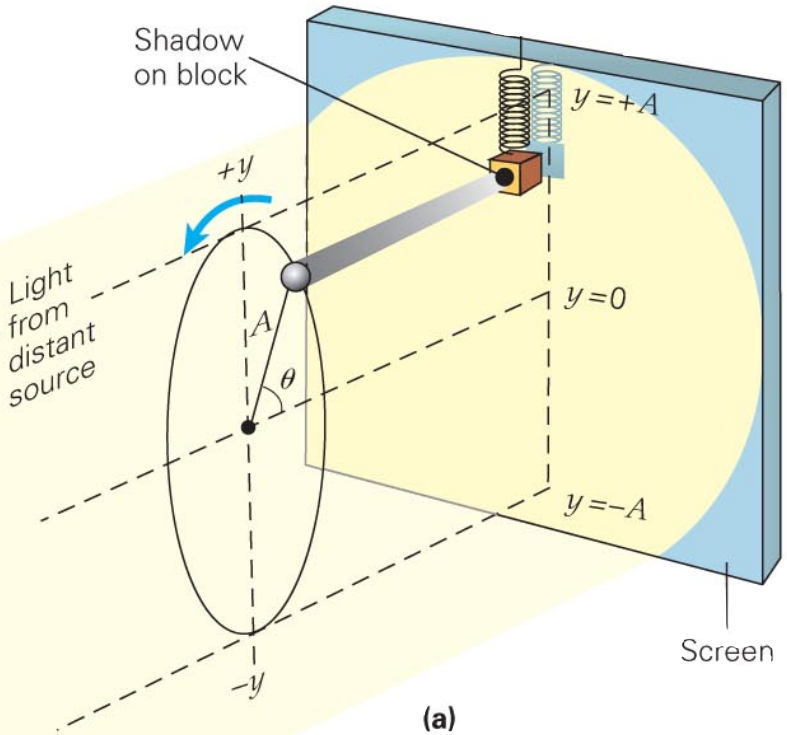
- The classic SHM
- SHM & uniform circular motion

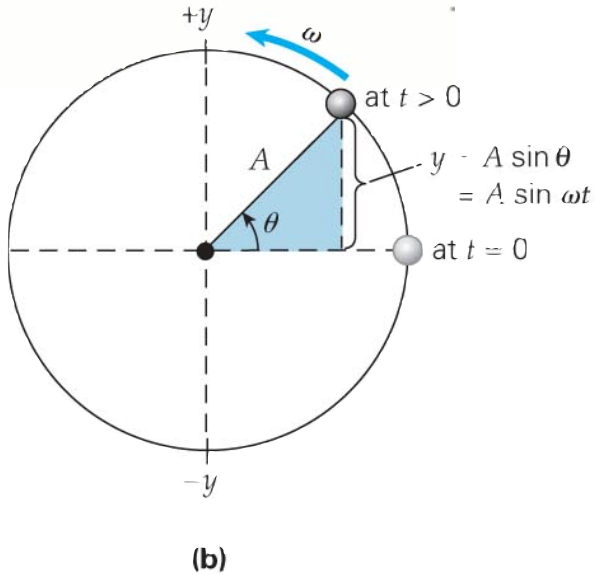
Real space



Phase space

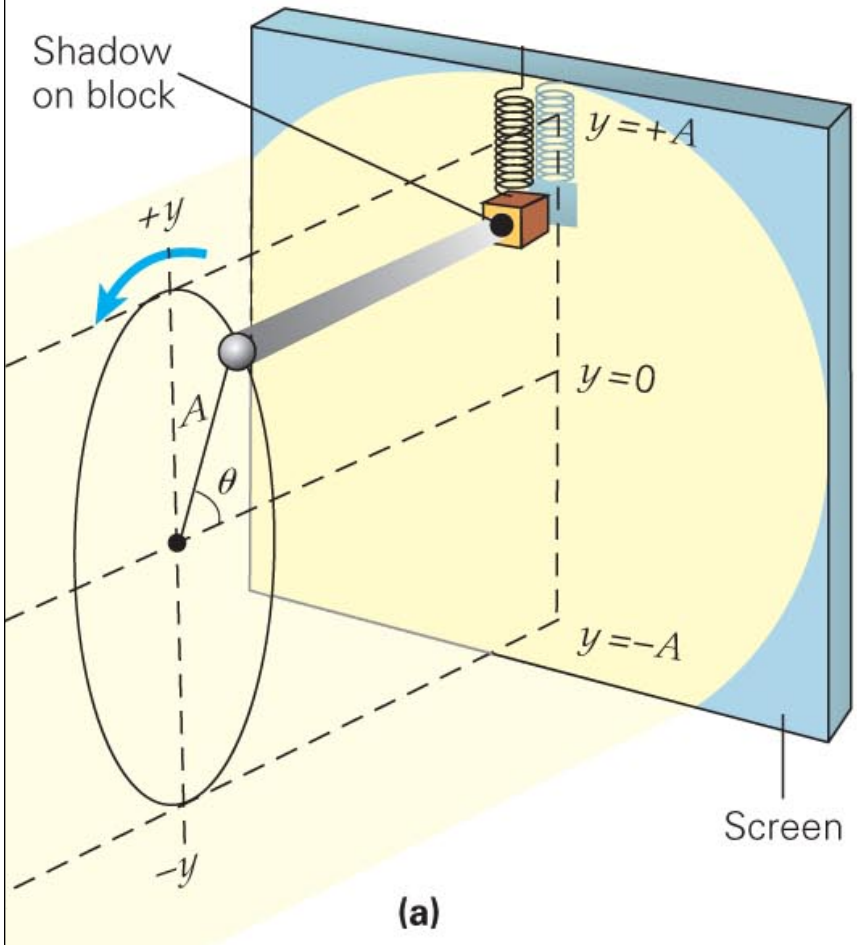




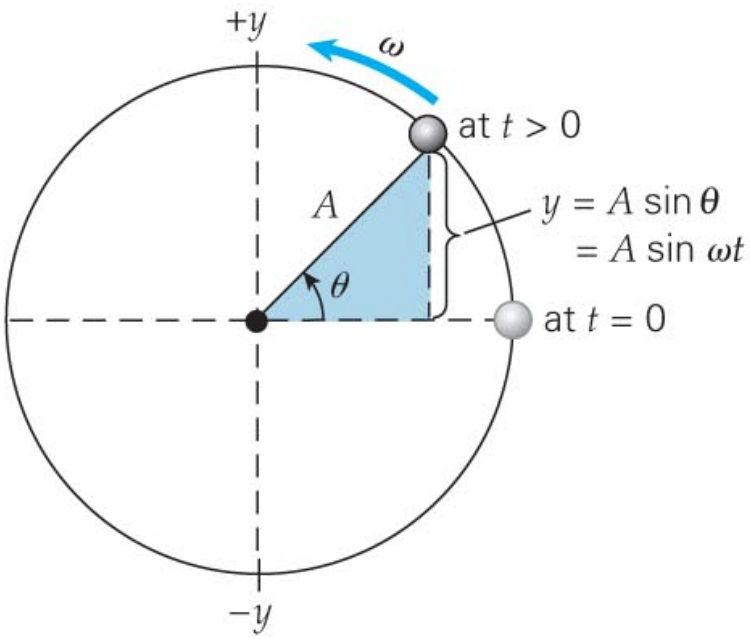


Equations of motion

- Equation of motion = function $x(t)$ describing motion



$$y = A \sin \omega t$$



Equations of motion

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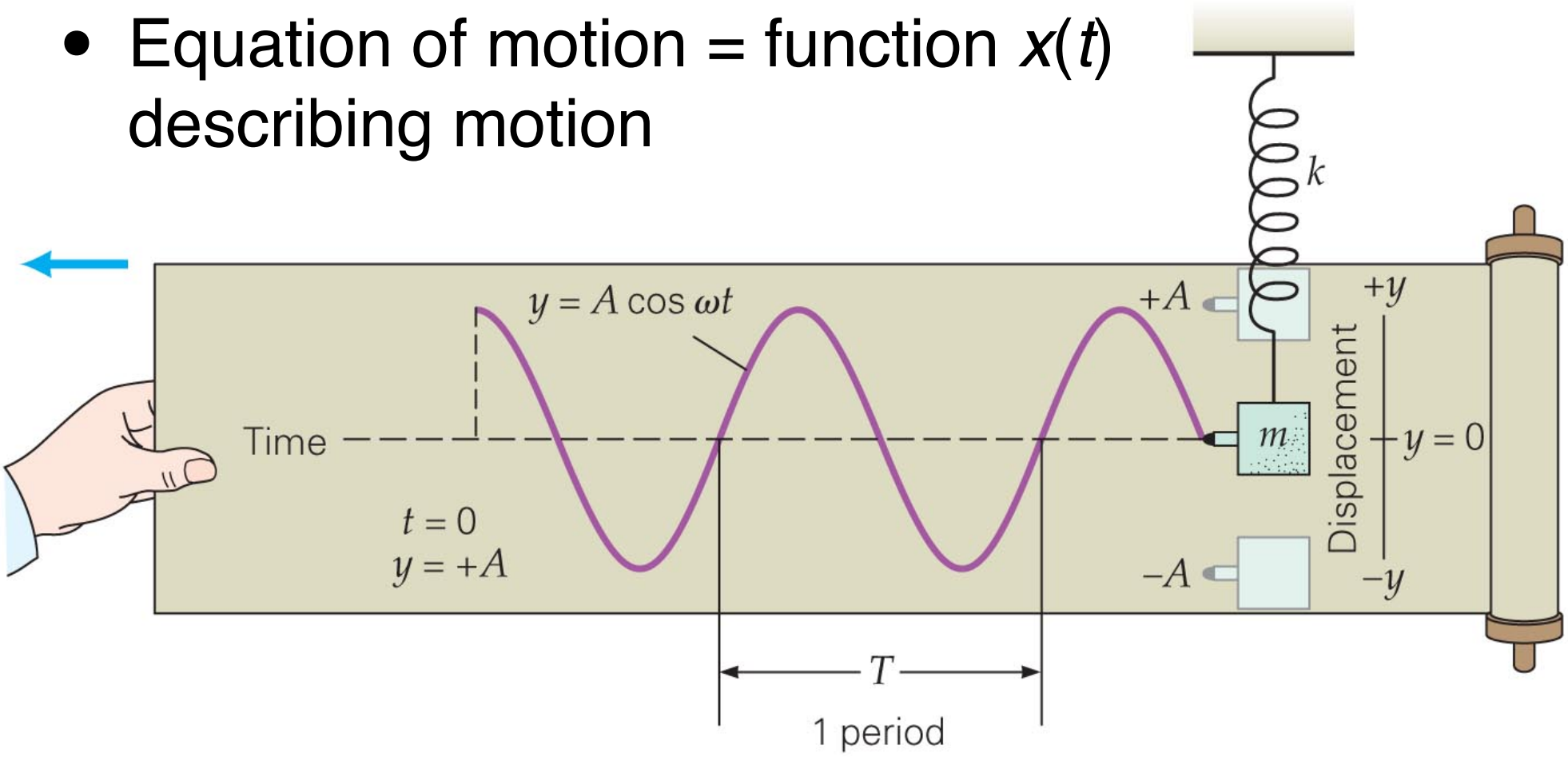
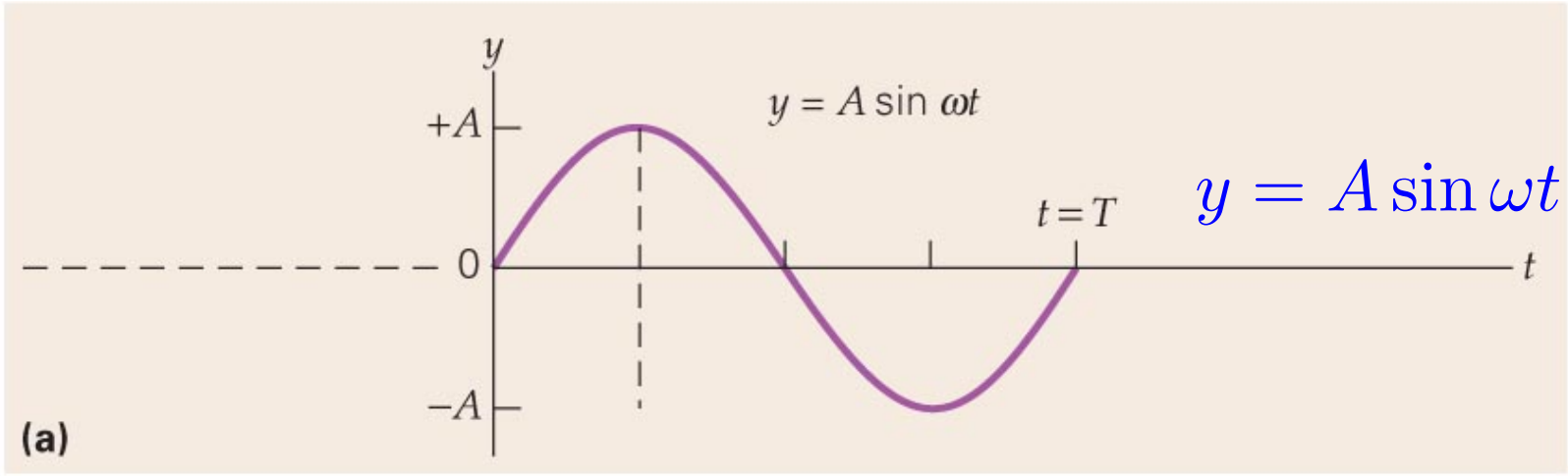
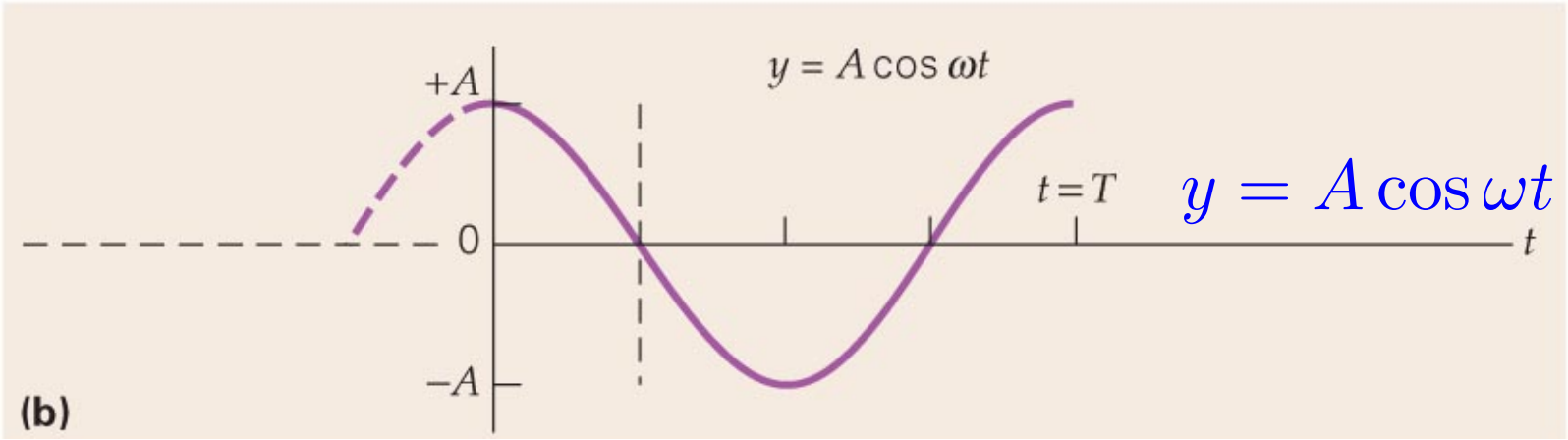


Equations of motion

- Equation of motion = function $x(t)$ describing motion



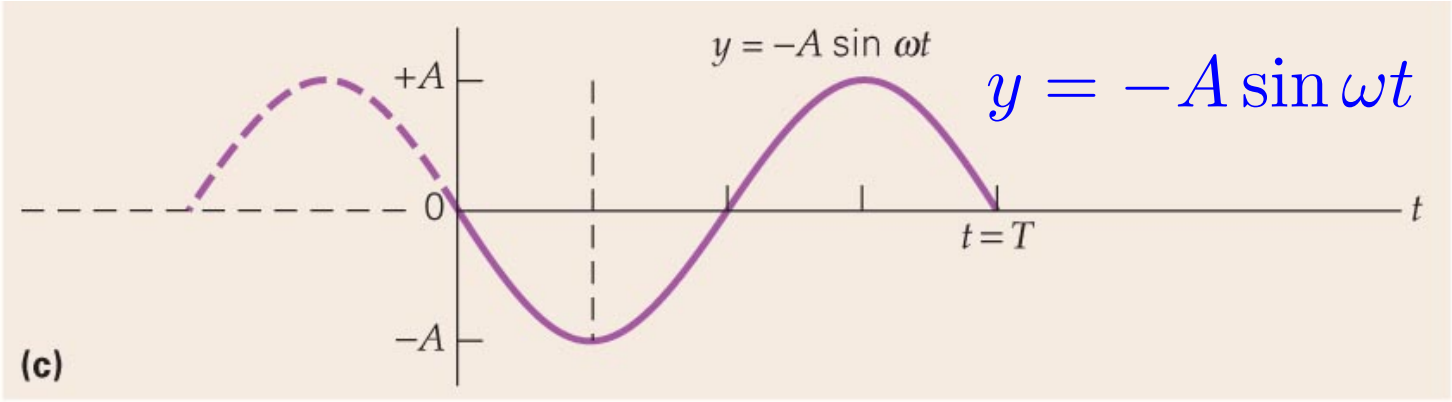
$y = A\sin\omega t$



$y = A\cos\omega t$

Equations of motion

- Equation of motion = function $x(t)$ describing motion



$$y = -A\sin\omega t$$

$$y = -A\cos\omega t$$

Equations of motion

- Summary: 4 possible equations of motion

$$y = A\sin\omega t \qquad y = -A\sin\omega t$$

$$y = A\cos\omega t \qquad y = -A\cos\omega t$$

- Strategy
  - Use the equation that satisfies the given initial conditions
  - Use radians for angles, set calculator to rad

Ex. 13.3: pothole

- Your car (m=1500 kg) has 4 wheels, each connected to an identical spring (shock) and bearing 1/4 of the car's mass.
  a) Empty car hits a pothole, bouncs at 1.2Hz. Spring const *k*?
  b) With 4 people (75 kg each) aboard, oscillation frequency f_{full}?

Which of the following is the *first* step to solve the problem?

A Draw a diagram
B Write what you know ("Given")
C Plug in numbers
D Read the problem carefully
☐ Write what you want to find ("Goal")

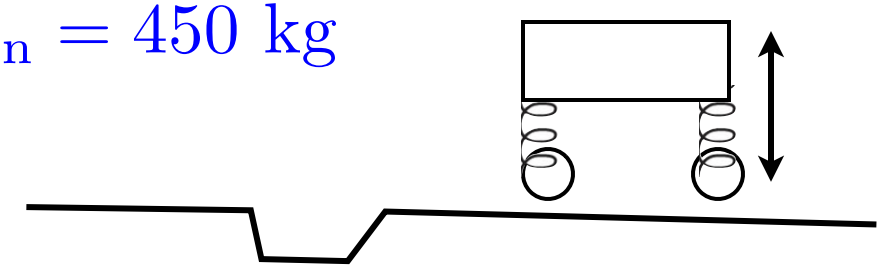
Ex. 13.3: pothole

- Your car (m=1500 kg) has 4 wheels, each connected to an identical spring, so each wheel bears 1/4 of the mass.

  a) Empty car hits a pothole, bouncs at 1.2Hz. Spring const *k*?
  b) With 4 people (75 kg each) aboard, oscillation frequency f_{full}?

Given: $m_{\text{empty}} = M_{\text{car}/4} = 375\ \text{kg} \quad f_{\text{empty}} = 1.2\ \text{Hz}$
$m_{\text{full}} = M_{\text{car}/4} + m_{\text{person}} = 450\ \text{kg}$

Goal: $k = ? \quad f_{\text{full}} = ?$



Principles & equations:

Simple harmonic motion, mass on spring

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

Strategy: get *k*, then can get *f* for any mass

Clicker question #120

- Compared to the empty car, the **frequency** of oscillation of the full car's springs is

$$m_{\text{empty}} = M_{\text{car}/4} = 375 \text{ kg}$$
$$m_{\text{full}} = M_{\text{car}/4} + m_{\text{person}} = 450 \text{ kg}$$

A Much (2x or more) smaller
B Slightly (less than 2x) smaller
C Unchanged
D Slightly (less than 2x) larger
Much (2x or more) larger

Ex. 13.3: pothole

Given: $m_{\text{empty}} = M_{\text{car}/4} = 375\ \text{kg} \quad f_{\text{empty}} = 1.2\ \text{Hz}$
$m_{\text{full}} = M_{\text{car}/4} + m_{\text{person}} = 450\ \text{kg}$

Goal: $k = ? \quad f_{\text{full}} = ?$

Principles & equations: $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ $\qquad f^2 = \frac{k}{4\pi^2 m}$

$4\pi^2 f^2 m = k$

Simple harmonic motion, mass on spring

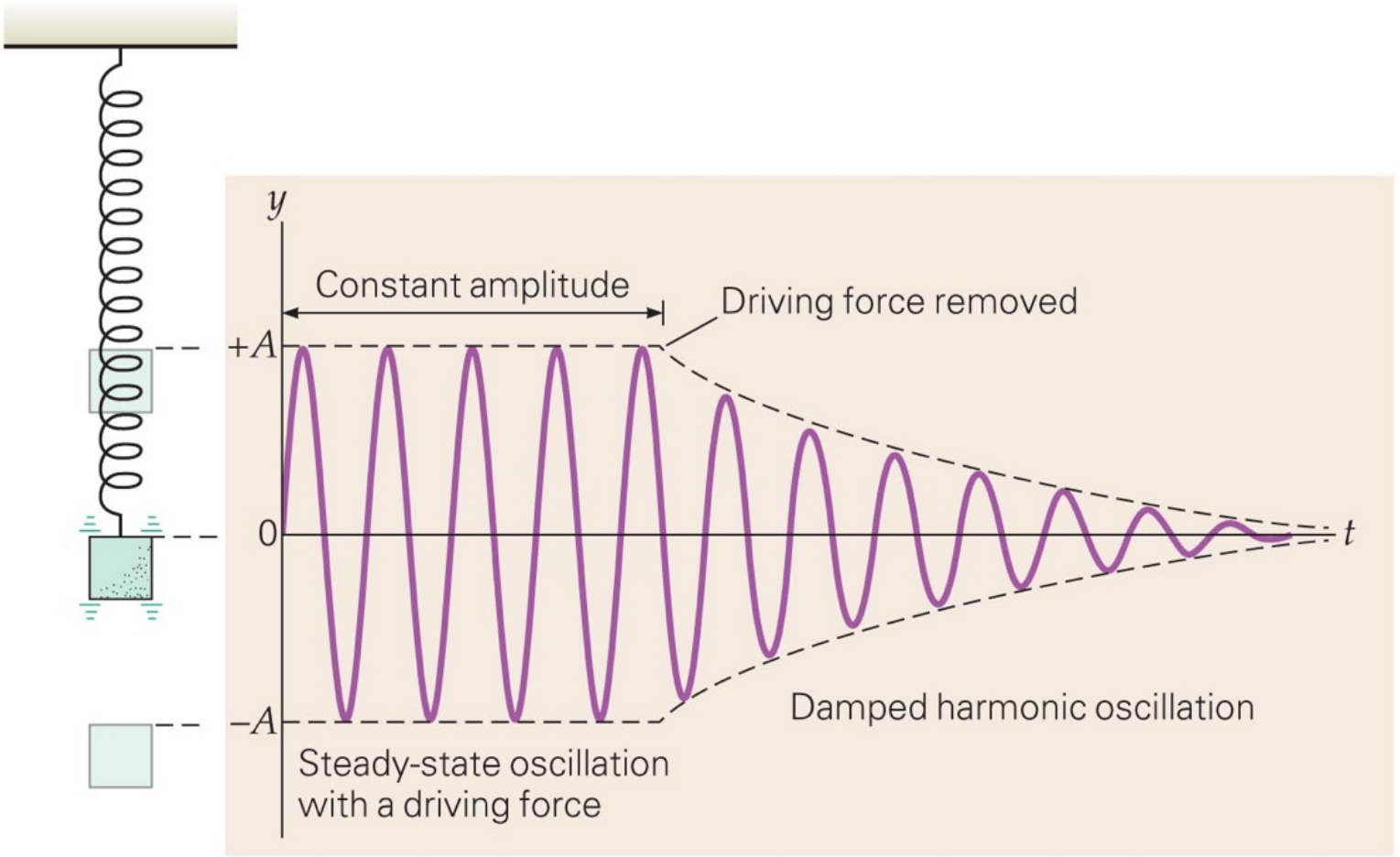
$$4\pi^2 f_{\text{empty}}^2 m_{\text{empty}} = k = 4\pi^2\,(1.2\ \text{Hz})^2\,(375\ \text{kg}) = 2.1 \times 10^4\ \text{N/m}$$

$$f_{\text{full}} = \frac{1}{2\pi}\sqrt{\frac{k}{m_{\text{full}}}} = \frac{1}{2\pi}\sqrt{\frac{2.1 \times 10^4\ \text{N/m}}{450\ \text{kg}}} = 1.1\ \text{Hz}$$

Reasonable?

Damped harmonic motion

- In real life, friction takes energy from oscillator
  - Amplitude decays exponentially



(a)

Clicker question #121

Question 13.11 Damped Pendulum

After a pendulum starts swinging, its amplitude gradually decreases with time because of friction.

What happens to the period of the pendulum during this time ?

A period increases

B period does not change

C period decreases

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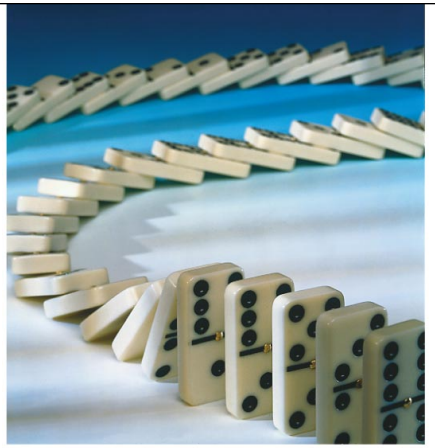
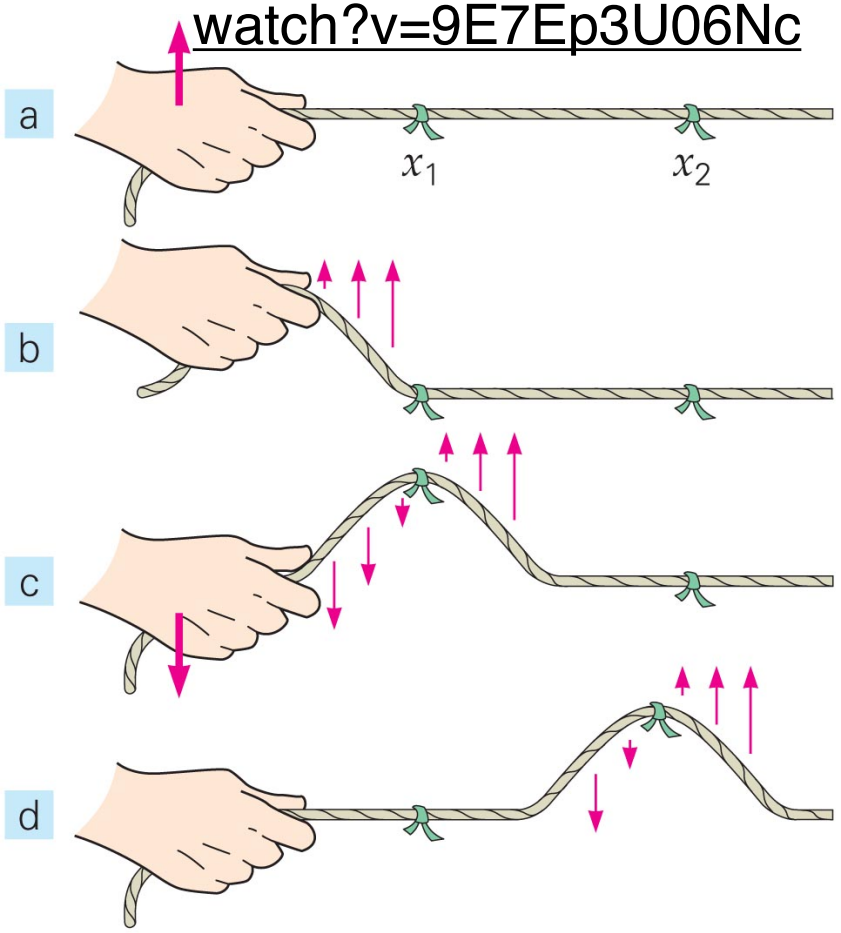
Wave motion

- Regular, rhythmic propagation of disturbance through space and time
  - Propagation through space: energy transferred
    - Wave pulse: return to equilibrium after pulse passes
  - Propagation through time: particles can oscillate in time as disturbance passes



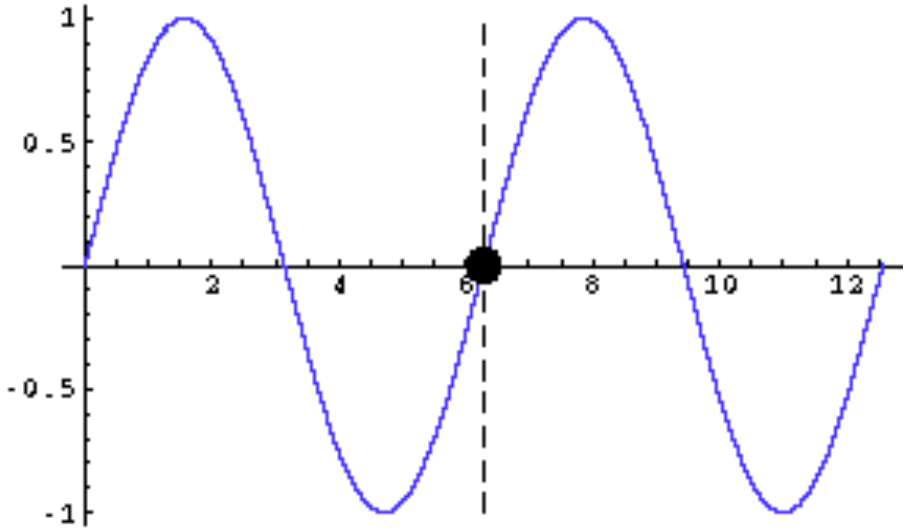
http://www.youtube.com/watch?v=9E7Ep3U06Nc



Periodic wave motion

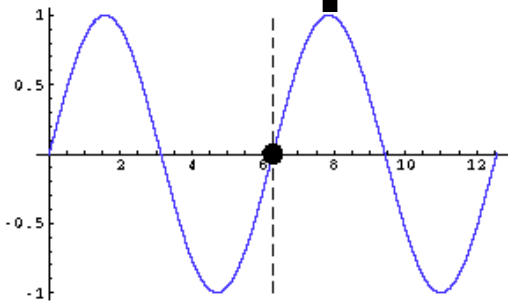
- Source: oscillating disturbance
- E.g.: source in simple harmonic motion
  - Sinusoidal in space: “snapshot” of wave is sine curve
  - Sinusoidal in time: each particle moves in SHM

$$y = A \sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right]$$



http://www.upscale.utoronto.ca/GeneralInterest/Harrison/Spectra/Spectra.html

Wave properties



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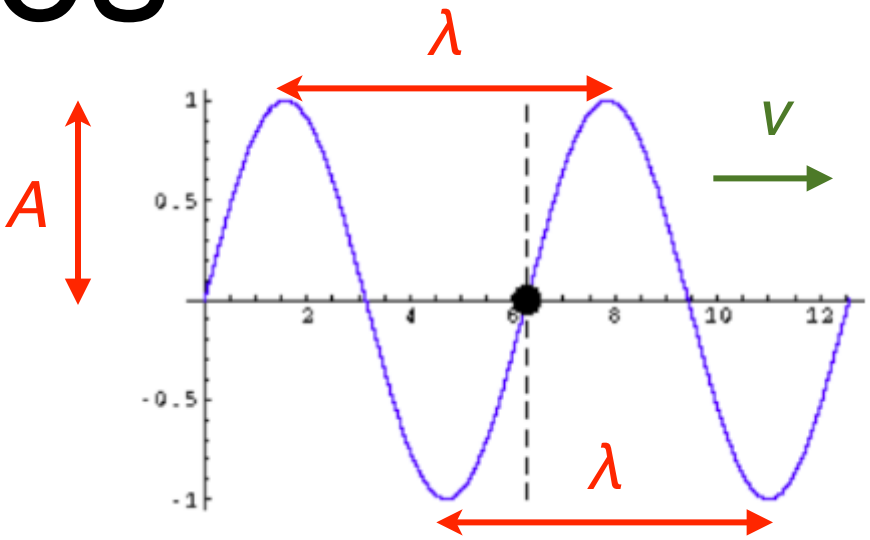


- Amplitude *A* = max. displacement
- Wavelength *λ* = crest-to-crest distance
- Period *T* = time for one wavelength to go by a given point
- Frequency *f* = number of wavelengths per second to go by
- Wave speed *v* = speed wave travels = 1 wavelength / period

$$v = \lambda/T = \lambda f$$

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

Clicker question #122

Question 13.15a Wave Motion I

Consider a wave on a string moving to the right, as shown below.

What is the direction of the velocity of a particle at the point labeled A ?

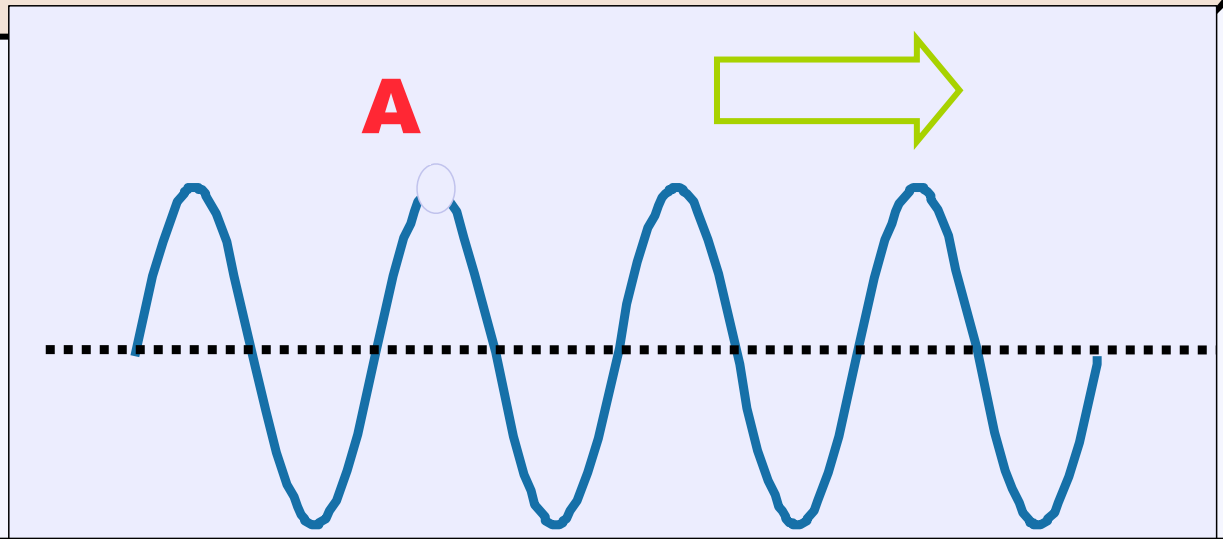
A →

B ↘

C ↓

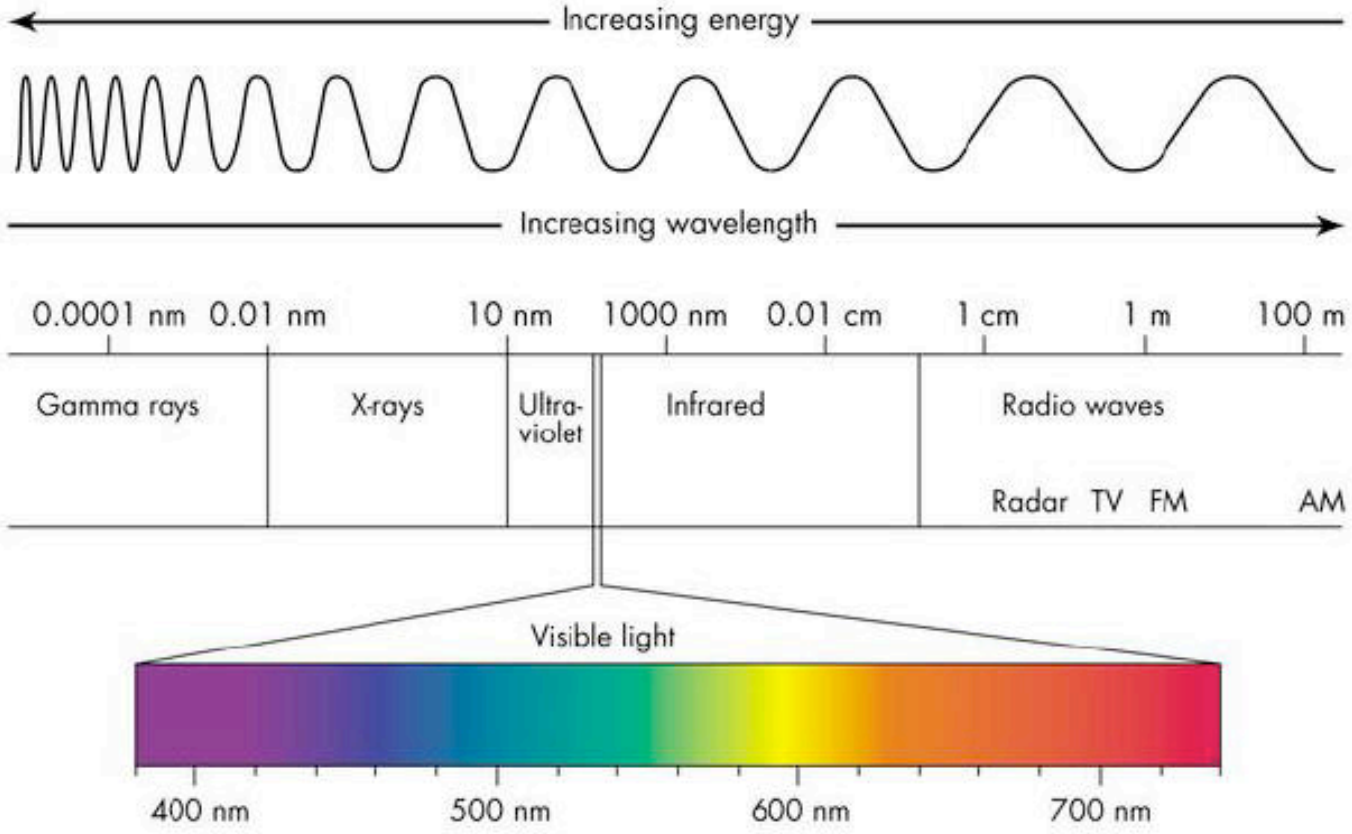
D ↑

the velocity is zero



Examples of waves

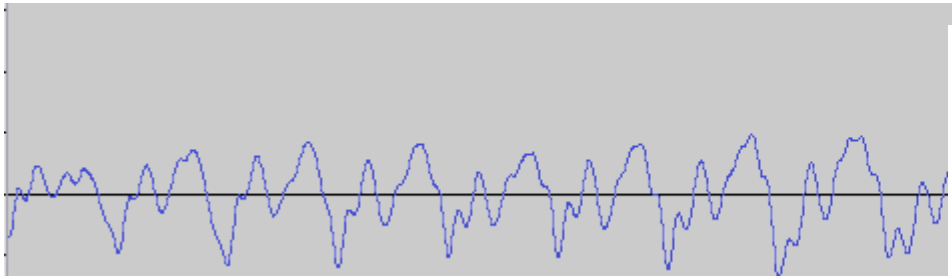
- Transverse, wave speed = speed of light
  - Electromagnetic waves (light, radio, x-ray, ...)

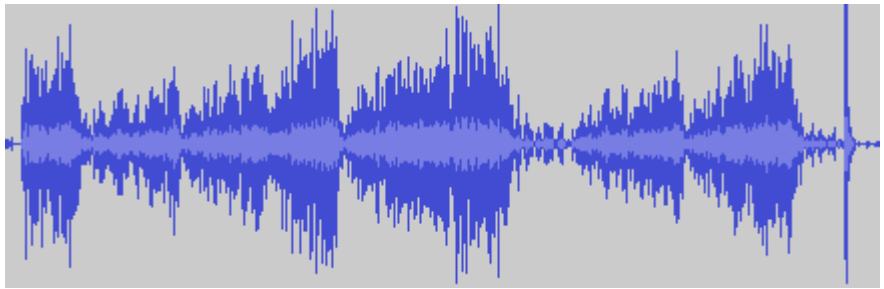


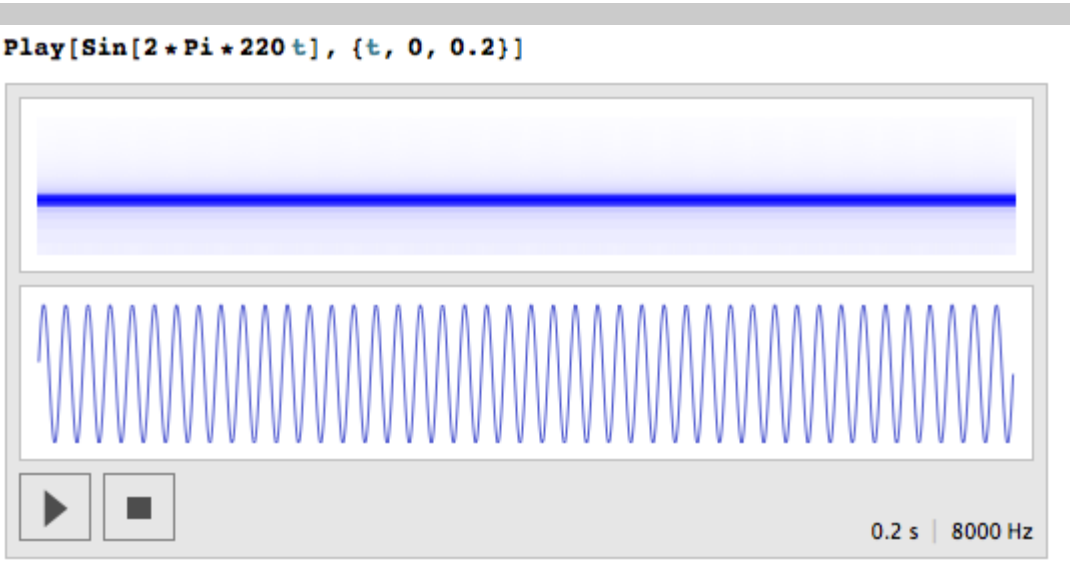
  - Gravitational waves…see Thursday's lecture

Examples of waves

- Transverse, wave speed = speed of light
- Longitudinal, wave speed = speed of sound = 340 m/s
  - Sound waves
    - Frequency f = 440 Hz for “A” above middle “C”
    - Double (halve) frequency to go up (down) octave
    - Music: superposition of many different sinusoidal waves
      https://sites.google.com/site/jasonrlovelace/scores-and-audio







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Student opinion questionnaire (SOQ)

- I will leave the room during this evaluation
- Procedure
  - Volunteer #1: Administer the evaluation
    - Read instructions aloud
    - Hand out evaluations
      - Beckman, Khalife, Koobatian, McMillan, Oh, Peek, & Ronilo get form FA12-20685-70
      - Everyone else gets form FA12-13159-01
    - Call time after 10 minutes.
    - Place back in envelope.
  - Volunteers #1 & #2: Take envelope to the physics dept. office
- Thank you for your feedback!