Physics 211

Sections 1 & 70
Dr. Geoffrey Lovelace
Fall 2012
Lecture 25 (12/06/12)

Lecture 25 outline

- Announcements
- Simple harmonic motion (SHM)
  - SHM, amplitude, period, frequency, energy
  - Connection to uniform circular motion
  - Demo & examples: mass on a spring & others
- Equations of motion for object in SHM
  - Position & initial conditions, velocity, accel.
  - Damping

Announcements

- Homework #11: out today, due 12/13 at 11:59PM
- Reading: Finish chapter 13: vibrations & waves
- Office hours: 10AM-11AM, 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)
- Tuesday: official student evaluations
  - Please bring a #2 pencil & eraser

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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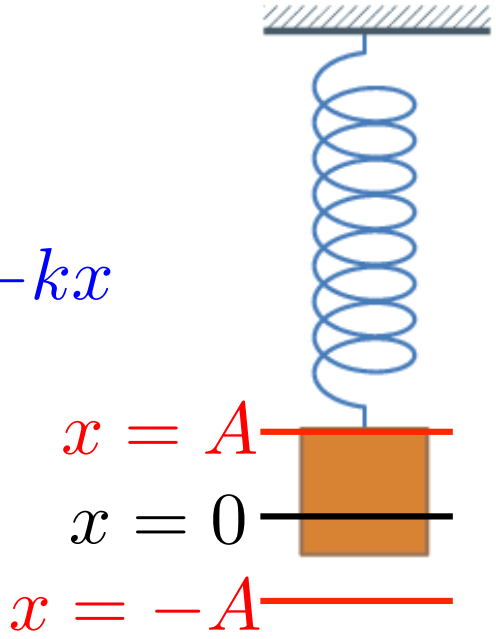
Simple harmonic motion (SHM)

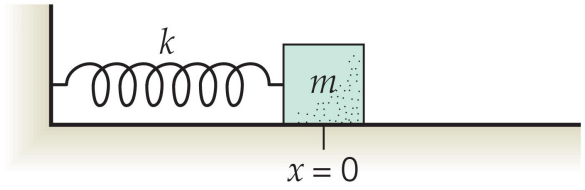
- SHM = oscillating ("back & forth") motion due to restoring force
  - "Simple:" simplest restoring force $F = -kx$
  - "Harmonic:" sin, cos describe motion
- Properties
  - Amplitude A = max. displacement x from equilibrium position
  - Period T = time of one cycle
  - Frequency f = cycles/s, angular frequency ω: rad/s
  - Energy: $E \propto A^2$



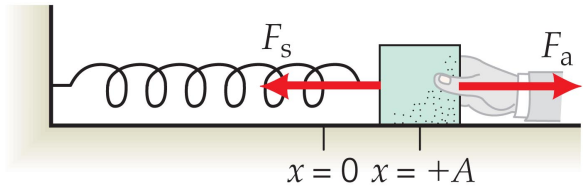
$$\omega = 2\pi f = \frac{2\pi}{T} \qquad f = \frac{1}{T}$$

Mass *m* on a spring *k*

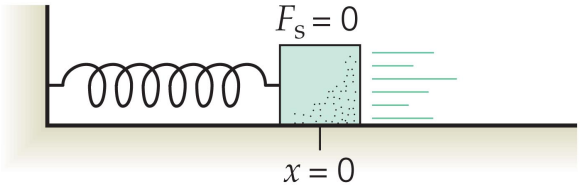
- Restoring force pulls toward equilibrium (*x*=0)



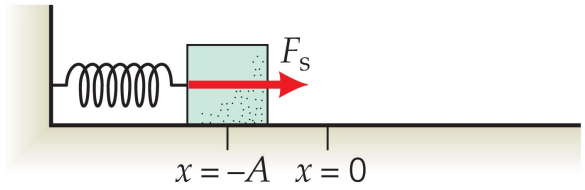
(a) Equilibrium



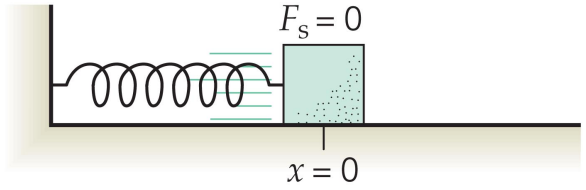
(b) $t = 0$ Just before release



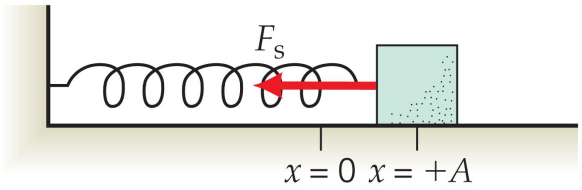
(c) $t = \frac{1}{4}T$



(d) $t = \frac{1}{2}T$



(e) $t = \frac{3}{4}T$



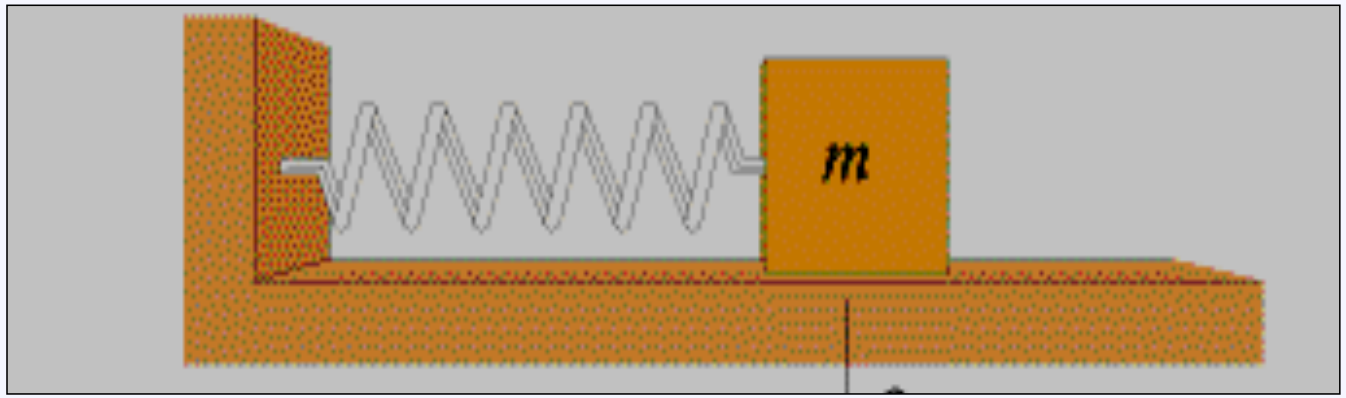
(f) $t = T$

Clicker question #114

Question 13.1a Harmonic Motion I

A mass on a spring in SHM has amplitude *A* and period *T*. What is the total distance traveled by the mass after a time interval *T*?

A. 0
B. *A*/2
C. *A*
D. 2*A*
4*A*



Clicker question #115

Question 13.1b Harmonic Motion II

A mass on a spring in SHM has amplitude *A* and period *T*. What is the net displacement of the mass after a time interval *T*?

A. 0
B. *A*/2
C. *A*
D. 2*A*
E. 4*A*

Clicker question #116

Question 13.2 Speed and Acceleration

A mass on a spring in SHM has amplitude *A* and period *T*. At what point in the motion is *v* = 0 and *a* = 0 simultaneously?

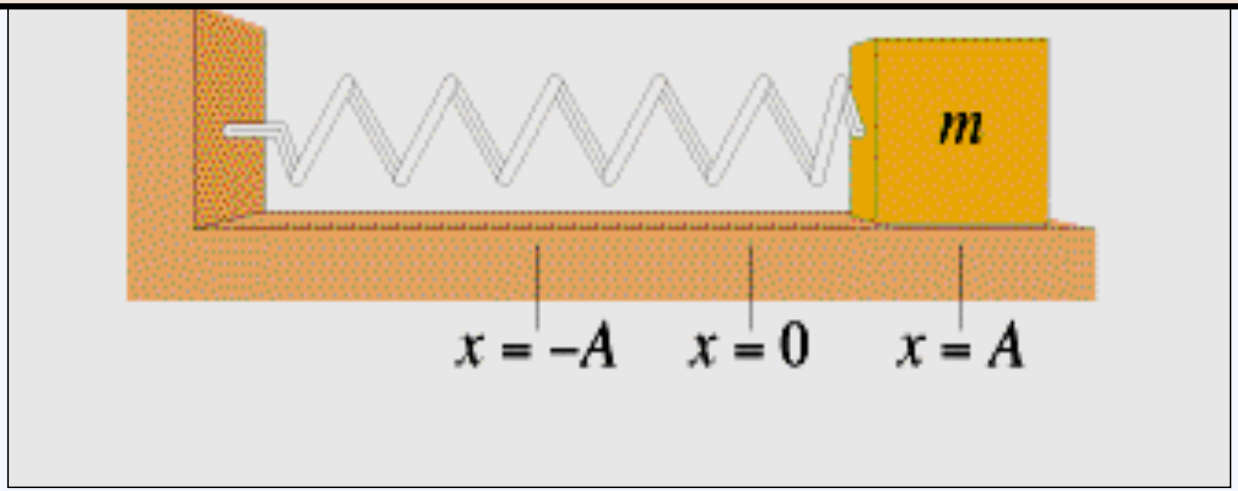
A. $x = A$

B. $x > 0$ but $x < A$

C. $x = 0$

D. $x < 0$

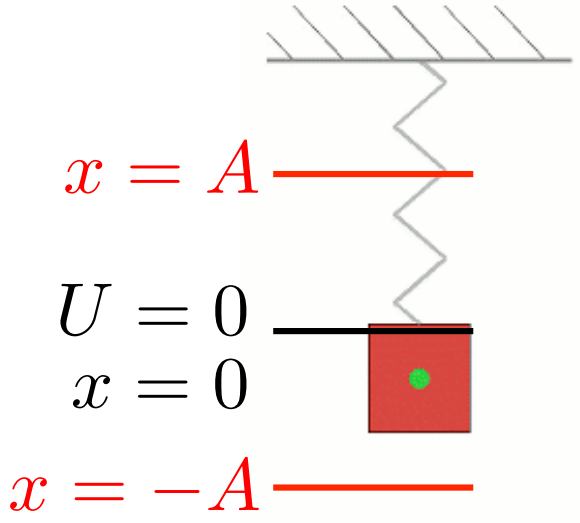
none of the above



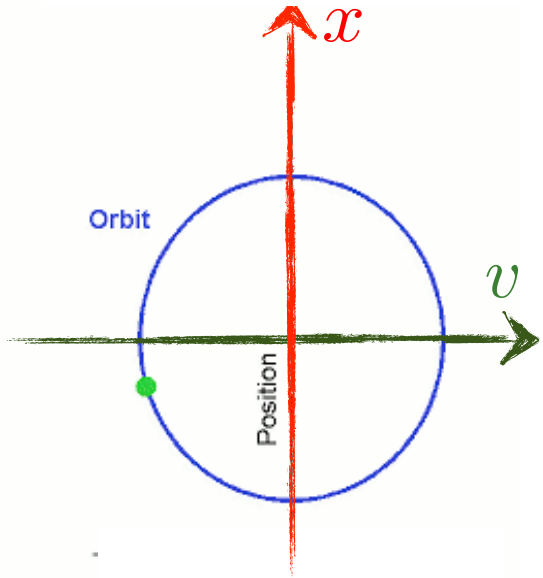
Mass *m* on a spring *k*

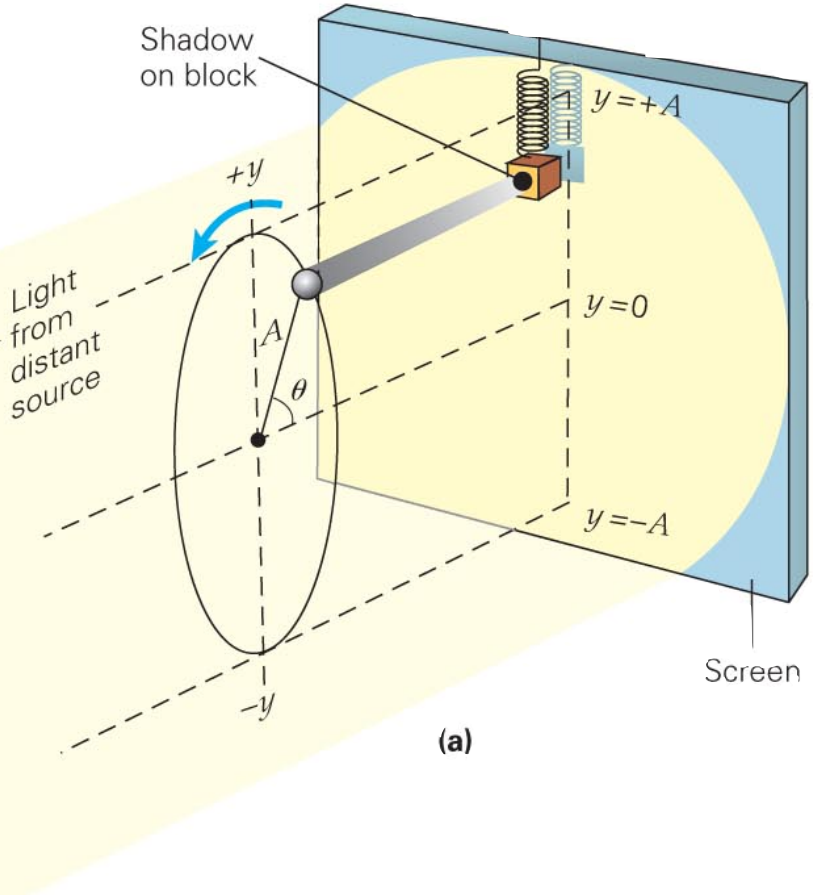
- The classic SHM
- SHM & uniform circular motion

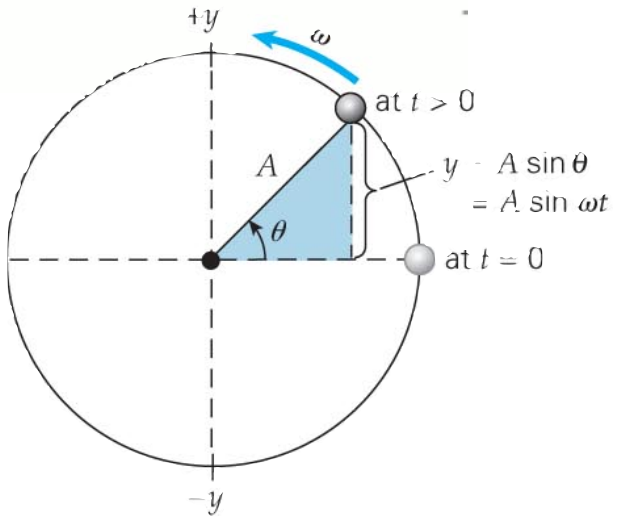
Real space



Phase space







Mass *m* on a spring *k*

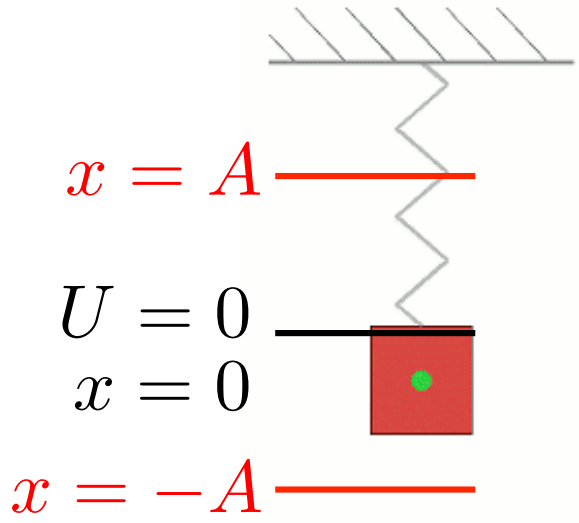
- The classic SHM
  - Restoring force

    $F = -kx$
  - Energy oscillates between kinetic, potential

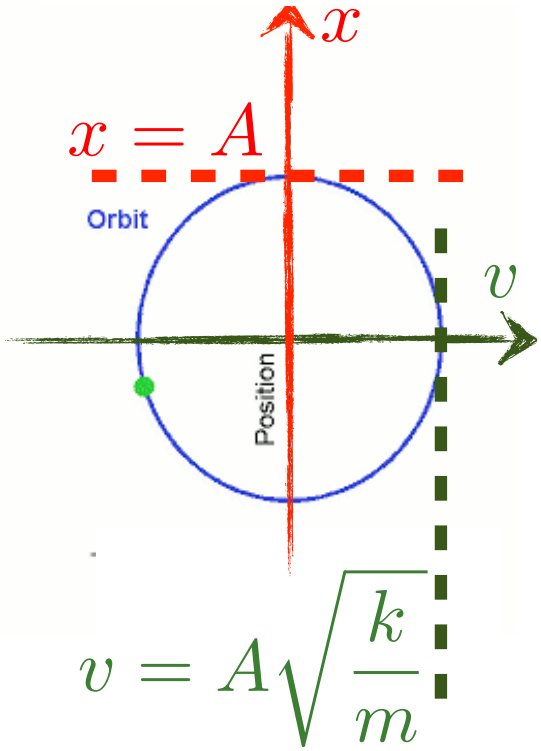
    $E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

    $E = \frac{1}{2}kA^2$
  - Period & frequency $T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}}$ $\omega = \sqrt{\frac{k}{m}}$

Real space

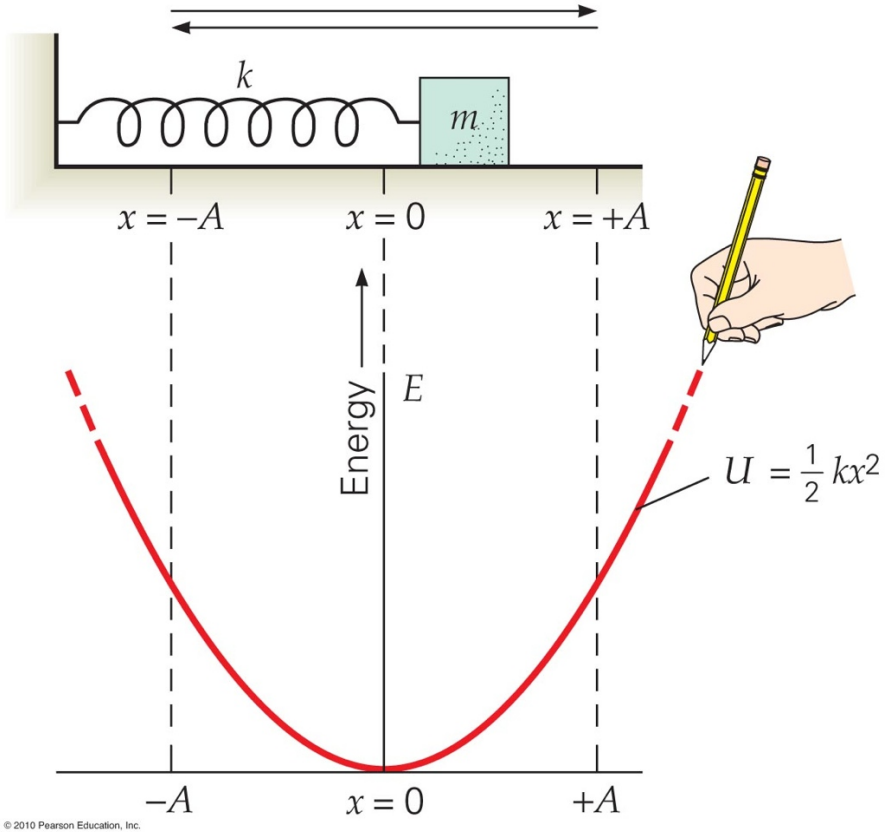


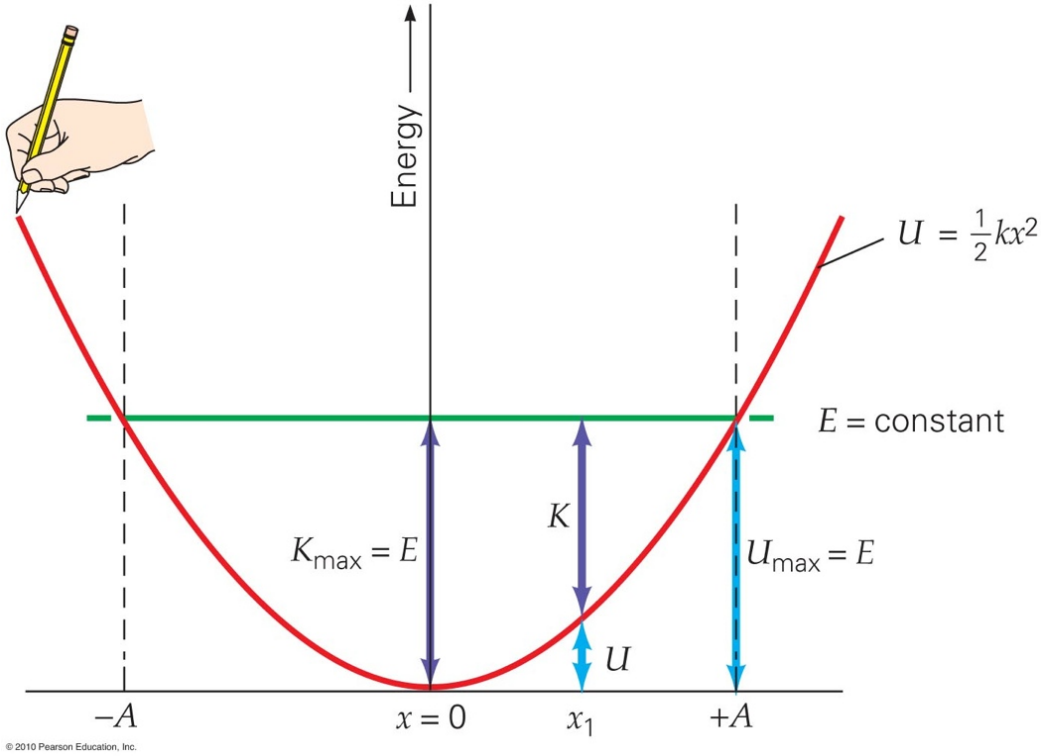
Phase space



Potential well

- A way to visualize energy exchange in SHM





- "Everything is a mass on a spring"
  - *Any* potential energy, near minimum, ≈ parabola

Clicker question #116

Question 13.5a Energy in SHM I

A mass oscillates in simple harmonic motion with amplitude A. If the mass is doubled, but the amplitude is not changed, what will happen to the total energy of the system?

A total energy will increase

B total energy will not change

C total energy will decrease

Clicker question #117

Question 13.5b Energy in SHM II

If the amplitude of a simple harmonic oscillator is doubled, which of the following quantities will change the most?

A frequency

B period

C maximum speed

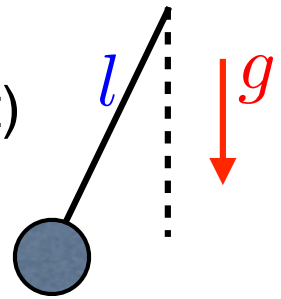
D maximum acceleration

total mechanical energy

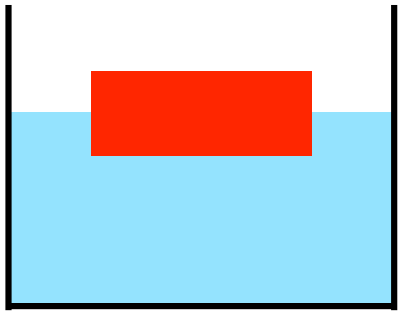
Other examples of SHM

- Pendulum
  (small angle displacement)

$$T = 2\pi\sqrt{\frac{l}{g}}$$



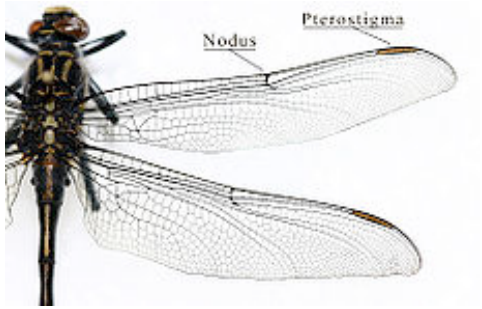
- Tuning fork & musical instruments, voltage from outlet
- Perturbed floating object
  mass *M*, cross-sectional area *a*,
  accel. of gravity *g*, water density *ρ*



$$T = 2\pi\sqrt{\frac{M}{\rho a g}}$$

- Insect wings

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



- Black hole after merger

http://www.youtube.com/watch?v=L478ZPy_2Ys

Clicker question #118

Question 13.8a **Period of a Pendulum I**

Two pendula have the same length, but different masses attached to the string. How do their periods compare?

A period is greater for the greater mass

B period is the same for both cases

C period is greater for the smaller mass

Clicker question #119

Question 13.4 To the Center of the Earth

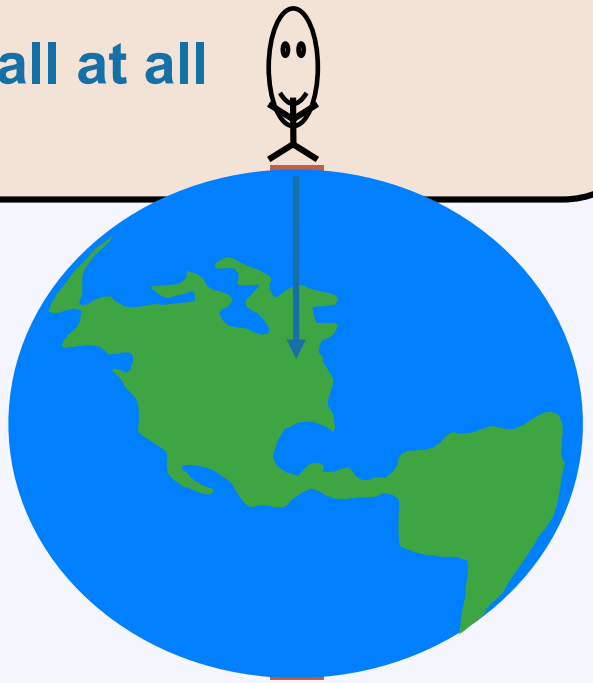
A hole is drilled through the center of Earth and emerges on the other side. You jump into the hole. What happens to you ?

A you fall to the center and stop

B you go all the way through and continue off into space

C you fall to the other side of Earth and then return

D you won't fall at all



Class participation

- 0. Full name
- 1. ***Question 13.9*** **Grandfather Clock**

A grandfather clock has a weight at the bottom of the pendulum that can be moved up or down. If the clock is running slow, what should you do to adjust the time properly?

A move the weight up

B move the weight down

C moving the weight will not matter

D call the repairman