Announcements 29 Apr 09

- **Homework #12**
  - Written homework due on Monday at the start of class
  - Online homework due on Tuesday by 8 am
- **Exam 3**
  - Wednesday May 6 from 7 to 9 pm
  - Make-up exams need to be scheduled no later than Friday this week!
  - See info on the blog

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Exam #3 Information (I)

- **What will be covered?**
  - Momentum (Chapter 9 of the textbook Secs. 1-5)
  - Energy and work (Chapter 10 Secs. 1-10 and Ch 11 Secs. 1-6)
  - Oscillations (Chapter 14 Secs. 1-7)
  - Material from homework assignments #9, #10, #11, #12
- **Exam format**
  - Multiple choice + 1 written problem
  - Mixture of conceptual questions (PRS like) and numerical problems (homework like)
  - Sample exam provided for practice (sample exam will be discussed during the special help session)

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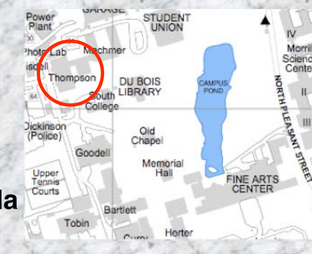
Exam #3 Information (II)

- Exam location on Wednesday May 6 from 7 to 9 pm
  - Location depends on the first letter of your last name:
    - A through F   THOM 102
    - G through O   THOM 104
    - P through Z   THOM 106



- What to take to the exam?
  - Calculator, #2 pencil, *hand-written* formula sheet + student ID
  - No book, no scratch paper (should not be needed)
- Resources
  - Help session on Monday May 4 from 5:30 to ~7:00 pm in HAS 20
  - Sample exam 3 + homework + lecture notes + MasteringPhysics Exam 3 practice + textbook problems (answers to odd-numbered problems are in the back of the book)

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Period dependence on the mass

DEMOS: Pendulum with timer
Mass connected to a spring with timer

How does the period of oscillation change when the oscillating mass increases?

The period of oscillation does not depend on the mass for the pendulum but it does for the vertical spring!

Why?

Pendulum:

$$(F_{net})_t = -\left(\frac{mg}{L}\right)s = ma$$

$$\Rightarrow a = -\left(\frac{g}{L}\right)s$$

Vertical spring:

$$(F_{net})_y = -ky = ma$$

$$\Rightarrow a = -\left(\frac{k}{m}\right)y$$

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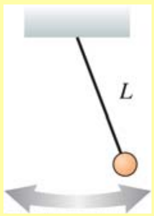
Period for pendulum and spring “oscillators”

Using energy conservation, one finds the period to only depend on the properties of the oscillating system, not on the amplitude of the oscillation



Pendulum:

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

Spring:

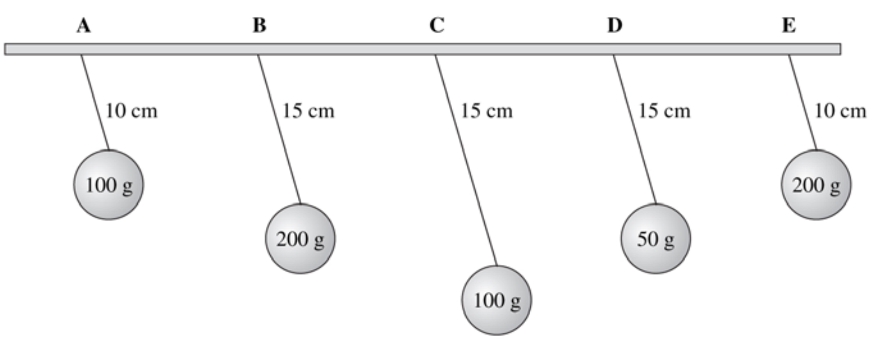
$$T = 2\pi\sqrt{\frac{m}{k}}$$

DEMO: Pendulum with timer & different lengths

Pendulum question

PRS

A series of pendulums with different length strings and different masses is shown below. Each pendulum is pulled to the side by the same (small) angle, the pendulums are released, and they begin to swing from side to side.

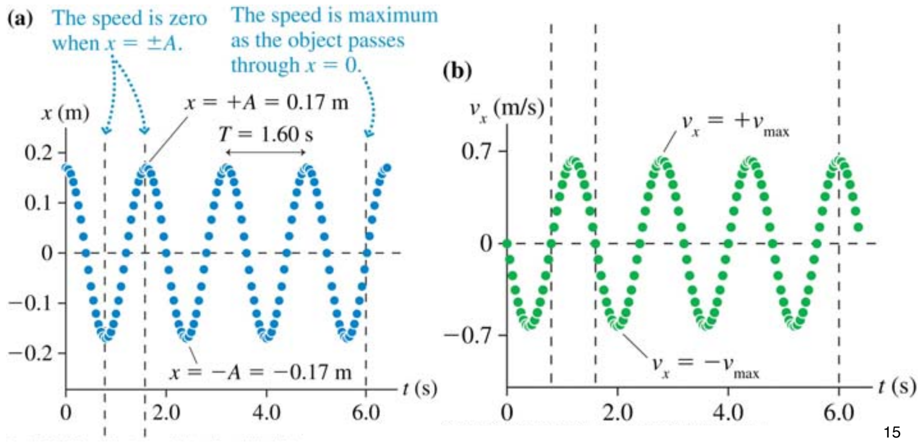


Which of the five pendulums has the highest frequency?

Position vs. time & velocity vs. time

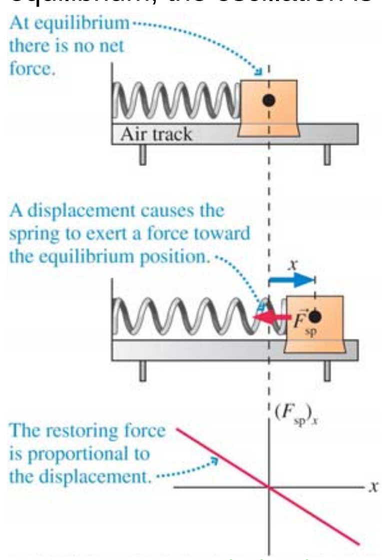
DEMOS: Mass connected to a vertical spring with ranger connected to computer

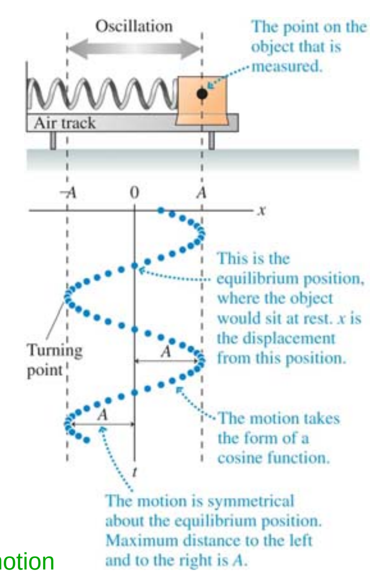
What does the position vs. time graph look like?
What does the velocity vs. time graph look like?



Linear Restoring Forces and *Simple Harmonic Motion*

If the restoring force is a linear function of the displacement from equilibrium, the oscillation is sinusoidal—simple harmonic motion

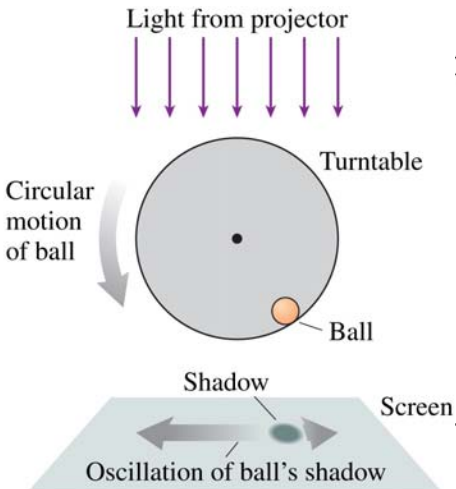


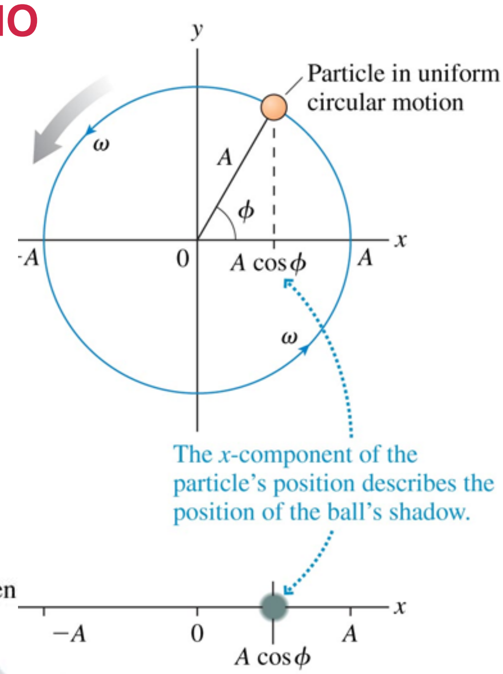


DEMO: Mass on a vertical spring vs. circular motion

Circular motion DEMO

Oscillation along x axis can be described in terms of circular motion





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Sinusoidal Relationships

Sinusoidal relationships

Exercise 6

A quantity that oscillates in time and can be written

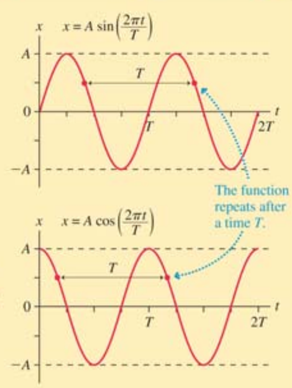
$$x = A\sin\left(\frac{2\pi t}{T}\right)$$

or

$$x = A\cos\left(\frac{2\pi t}{T}\right)$$

is called a **sinusoidal function** with **period** T. The argument of the functions, $2\pi t/T$, is in radians.

The graphs of both functions have the same shape, but they have different initial values at $t = 0$ s.



LIMITS If x is a sinusoidal function, then x is

- *bounded*—it can only take values between A and $-A$.
- *periodic*—it repeats the same sequence of values over and over again. Whatever value x has at time t, it has the same value at $t + T$.

SPECIAL VALUES The function x has special values at certain times:

	$t = 0$	$t = \frac{1}{4}T$	$t = \frac{1}{2}T$	$t = \frac{3}{4}T$	$t = T$
$x = A\sin(2\pi t/T)$	0	A	0	$-A$	0
$x = A\cos(2\pi t/T)$	A	0	$-A$	0	A

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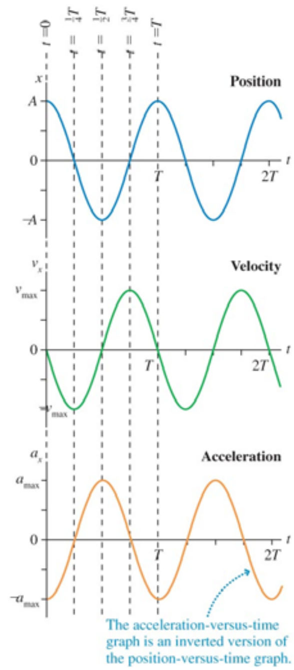
Mathematical Description of Simple Harmonic Motion

Eq. (14.18)

$$x(t) = A\cos(2\pi ft)$$
$$v_x(t) = -(2\pi f)A\sin(2\pi ft)$$
$$a_x(t) = -(2\pi f)^2 A\cos(2\pi ft)$$

Position, velocity, and acceleration for an object in simple harmonic motion with frequency f and amplitude A

Notation: x(t) means position x is a function of time t, it doesn't mean x multiplied by t



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Position problem

The position of a 60 g oscillating mass is $x = 5$ cm at $t = 0$. Its period of oscillation is 2.0 s and its amplitude is 5.0 cm. Find its position and velocity at $t = 3.2\ s$.

Know:

$A = 5.0\ cm = 0.05\ m$

$T = 2.0\ s$

Find: x, v_x at $t = 3.2\ s$

$$x(t) = A\cos(2\pi f t)$$
$$v_x(t) = -(2\pi f)A\sin(2\pi f t)$$
$$a_x(t) = -(2\pi f)^2 A\cos(2\pi f t)$$

frequency:

$$f = \frac{1}{T} = \frac{1}{2.0\ s} = 0.5\ s^{-1}$$

angular frequency:

$$\omega = 2\pi f = \frac{2\pi}{T} = 3.14\ s^{-1}$$

Make sure to set your calculator to radians!

$$x(t = 3.2s) = (0.05m)\cos\left(3.14s^{-1} \times 3.2s\right) = -0.041m$$

$$v_x(t = 3.2s) = -\left(3.14s^{-1}\right)(0.05m)\sin\left(3.14s^{-1} \times 3.2s\right) = -0.92m/s$$

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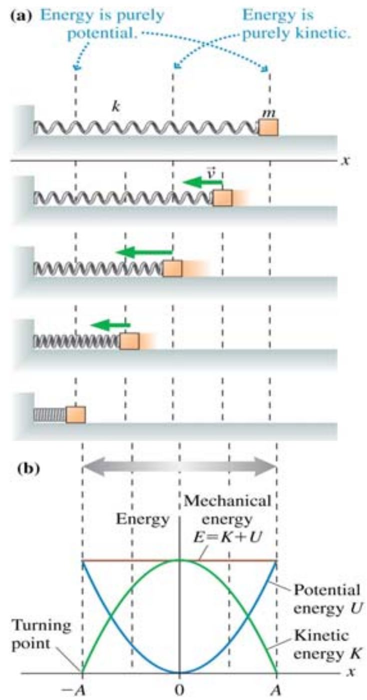
Energy in Simple Harmonic Motion

As a mass on a spring goes through its cycle of oscillation, energy is transformed from potential to kinetic and back to potential

Mechanical energy is conserved if friction is negligibly small



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Solving Problems

TACTICS BOX 14.1 **Identifying and analyzing simple harmonic motion**

Exercise 11

1. If the net force acting on a particle is a linear restoring force, the motion is simple harmonic motion around the equilibrium position.
2. The position, velocity, and acceleration as a function of time are given in Equation 14.18. The equations are given here in terms of x, but they can be written in terms of y, θ, or some other variable if the situation calls for it.
3. The amplitude A is the maximum value of the displacement from equilibrium. The maximum speed and the maximum magnitude of the acceleration are $\boxed{v_{max} = (2\pi f)A}$ and $\boxed{a_{max} = (2\pi f)^2 A}$.
4. The frequency f (and hence the period $T = 1/f$) depends on the physical properties of the particular oscillator, but f does *not* depend on A.

   For a mass on a spring, the frequency is given by $f = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$.
5. Mechanical energy is conserved. As the oscillation proceeds, energy is transformed from kinetic to potential energy and then back again.

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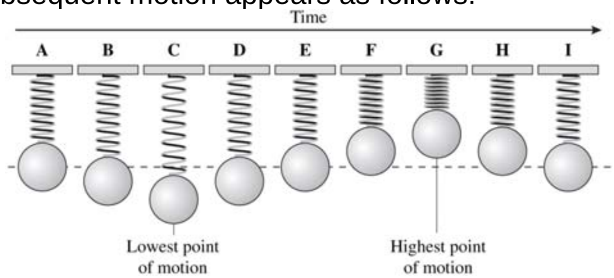
Oscillating motion question

PRS

A ball on a spring is pulled down and then released. Its subsequent motion appears as follows:



1) At which of the above times is the displacement zero?
2) At which of the above times is the velocity zero?
3) At which of the above times is the acceleration zero?
4) At which of the above times is the kinetic energy a maximum?
5) At which of the above times is the potential energy a maximum?
6) At which of the above times is kinetic energy being transformed to potential energy?
7) At which of the above times is potential energy being transformed to kinetic energy?

Answers:
1. A,E,I
2. C,G
3. A,E,I
4. A,E,I
5. C,G
6. B,F
7. D,H

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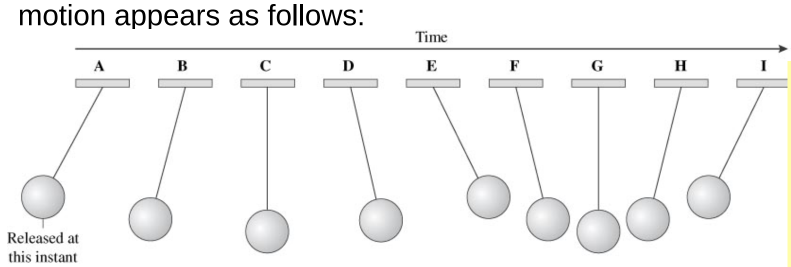
Oscillating motion question

PRS

A pendulum is pulled to the side and released. Its subsequent motion appears as follows:



1) At which of the above times is the displacement zero?
2) At which of the above times is the velocity zero?
3) At which of the above times is the acceleration zero?
4) At which of the above times is the kinetic energy a maximum?
5) At which of the above times is the potential energy a maximum?
6) At which of the above times is kinetic energy being transformed to potential energy?
7) At which of the above times is potential energy being transformed to kinetic energy?

Answers:
1. C,G
2. A,E,I
3. C,G
4. C,G
5. A,E,I
6. D,H
7. B,F

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