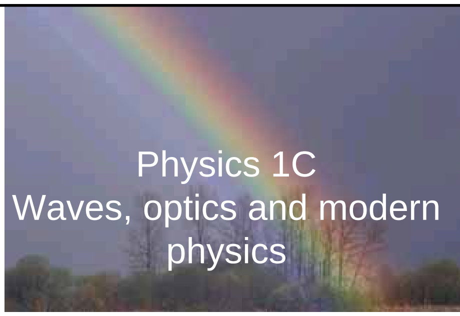


Instructor: Melvin Okamura
email: mokamura@physics.ucsd.edu

Course Information

Course Syllabus on the web page http://physics.ucsd.edu/students/courses/fall2009/physics1c

Instructor: Mel Okamura – mokamura@physics.ucsd.edu
Office: 4517Mayer Hall Addition
Office Hrs. Mon 2-3 pm or by appointment

TA: Chris Murphy
Office: TBA
Office Hrs: TBA

Text. Physics 1 Serway and Faughn, 7^{th} edition, UCSD custom edition. Volume 1 and Volume 2

Class Schedule

- **Lectures**
  - Tu, Thu. 11:00-12:20 pm York Hall 2722
- **Quizzes**
  - Third Tue.
  - 11:00-12:200 pm York Hall 2722
- **Problem Session**
  - TBA

Grades

- Quizzes (3) will be held on Tue as scheduled. You are allowed to drop 1 quizzes. There will be no make-up quizzes.
- Final exam covering the whole course.
- The final grade will be based on

  Quizzes 60% (best 2 out of 3 quizzes)
  Final exam 40%
  Extra credit 5% (clicker responses)

Homework

- Homework will be assigned each week.
- Homework will not be graded but quiz questions will resemble the homework.
- Solutions to the homework problems will be posted on the web page.

Clickers

Interwrite Personal Response System (PRS)
Available at the bookstore

Clicker questions will be asked during class. Student responses will be recorded.
2 points for each correct answer
1 point for each incorrect answer.

The clicker points (up to 5%) will be added to your score at the end of the quarter

Laboratory

- The laboratory is a separate class which will be taught by Professor Anderson.

Waves and Modern Physics

- Oscillations and Waves
  - Sound, light, radio waves, microwaves
- Optics
  - Lenses, mirrors, cameras, telescopes.
  - Interference, diffraction, polarization
- Quantum Mechanics
  - Quantum mechanics, atoms, molecules, transistors, lasers
- Nuclear Physics
  - Radioactivity, nuclear energy

1.1 Simple Harmonic Motion

- Kinematics – Sinusoidal motion
- Dynamics -Newton's law and Hooke's law.
- Energetics – Conservation of Energy
- Examples
  - Mass on a spring
  - Pendulum

Properties of SHM

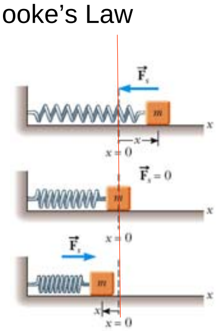
- Time for oscillations is independent of the amplitude of the oscillation.
- Useful as a timing device.

SHM is exhibited by mechanical systems which follow Hooke's Law

Hooke's Law

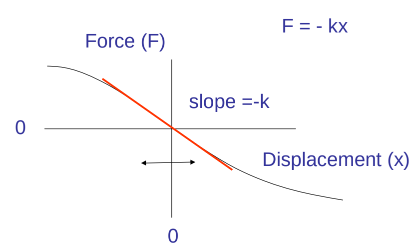
$$\vec{F} = -k\vec{x}$$

F - Force
k - Force constant Units (N/m)
x – displacement from equilibrium position



Equilibrium position

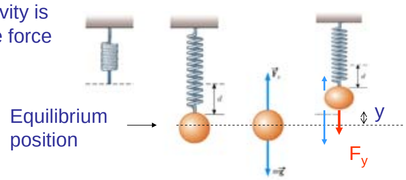
Hooke's Law



Hooke's law almost always holds for small displacements

Vertical direction

The force of gravity is cancelled by the force of the spring.

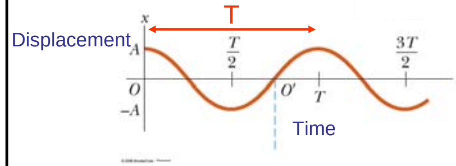


The force on the object is proportional to the displacement from the equilibrium position.

$$\vec{F}_y = -k\vec{y}$$

Hooke's Law is obeyed.

Description of Simple Harmonic Motion



$$x = A\cos\omega t$$

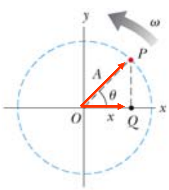
Amplitude - A (maximum displacement, m)

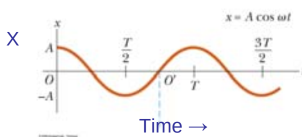
Period - T (repeat time, s)

Frequency - $f = \frac{1}{T}$ Cycles/s (Hertz)

Angular Frequency $\omega = 2\pi f$ = (radians /s)

sinusoidal function





The projection of the rotating vector A on the x axis generates a sinusoidal function useful in visualizing sinusoidal motion.

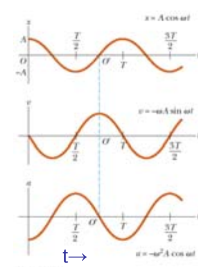
$$x = A\cos(\theta) = A\cos(\frac{2\pi}{T}t) = A\cos(2\pi f t) = A\cos(\omega t)$$

displacement, velocity, acceleration

$$x = A\cos(\omega t)$$

$$v = \frac{dx}{dt} = -\omega A\sin(\omega t)$$

$$a = \frac{dv}{dt} = -\omega^2 A\cos(\omega t)$$



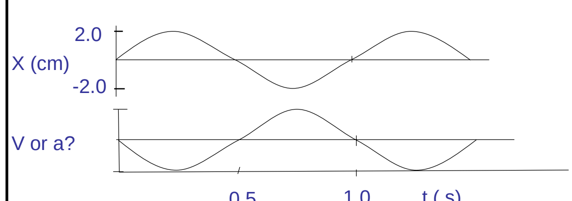
x, v and a are sinusoidal functions with different initial phase angles.
The magnitudes of v and a are multiplied by ω or ω^2 to preserve the units.

Example

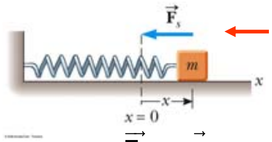
A mass on a spring is oscillating with a period of 0.5 s and amplitude of 2.0 cm.

What is the frequency?
What is the angular frequency?
What is the maximum speed?
What is the maximum acceleration?
What is the position of the mass when the speed is maximum?
What is the position of the mass when the acceleration is maximum?

The top trace shows the displacement vs time for a harmonic oscillator. Does the bottom trace show the value of v or a?



The frequency is determined by Newton's Law



$\vec{a}$

$$\vec{F_s} = m\vec{a}$$

$$\left.\begin{aligned} F_s &= -kx = -kA\cos\omega t \\ ma &= -m\omega^2 A\cos\omega t \end{aligned}\right\}$$ For sinusoidal motion.

gives

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

Frequency of the mass on a spring

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

F=-ky

m

How does the period depend on mass?

How does the period depend on the force constant?

How does the period depend on the amplitude?

Demo

Find the force constant of a spring and calculate the oscillation frequency.

Problem

A 75 kg student steps into a car with a mass of 1500 kg and the car is displaced downward by 1.0 cm. As she drives off she goes over a bump and the car (which has poor shock absorbers) oscillates. What is the frequency of oscillation.

Springs in parallel

Suppose you had two identical springs each with force constant k from which an object of mass m was suspended. The oscillation period for one spring is T_o.

What would the oscillation period be if the two springs were connected in parallel?

A. $2T_o$
B. $T_o/2$
C. $2^{1/2}T_o$
D. $T_o/2^{1/2}$

Springs in series

Suppose you had two identical springs each with force constant k from which an object of mass m was suspended. The oscillation period for one spring is T_o.

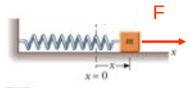
What would the oscillation period be if the two springs were connected in series?

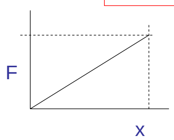
A. $2T_o$
B. $T_o/2$
C. $2^{1/2}T_o$
D. $T_o/2^{1/2}$

Energy

Energy required to stretch (compress) a spring by a displacement x

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



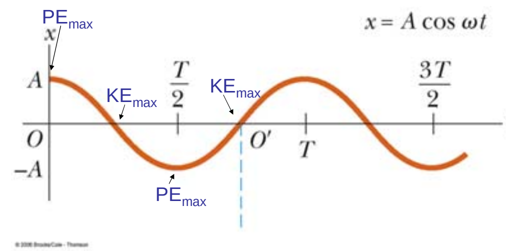


Work = $F_{average}$ x

$F_{average}$ =½ kx

Note the energy depends on x^2 so it is independent of the sign of x, i.e. same for compression and stretch.

Oscillation between KE and PE
Total energy =KE+PE = constant



Pendulum

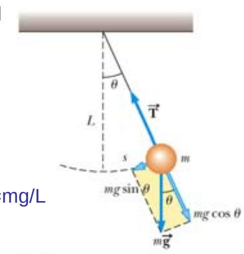
The restoring force is proportional to the displacement for small displacements.

$$F = -mg\sin\theta$$

$$F = -mg\theta \quad \text{for small } \theta$$

$$F = -\frac{mg}{L}s$$

Equivalent to Hooke's Law with k=mg/L



$\omega = \sqrt{\frac{k}{m}}$ then becomes

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

The period is dependent on L but independent of m

Question

How can you determine the value of g using a pendulum?

Question

How does the period of a pendulum depend on L?

How does the period depend on M?

How does the period depend on amplitude?

Question

Suppose you drop a ball to the floor and it rebounds after a perfectly elastic collision with the floor and continues to bounce.

Does the ball display simple harmonic motion?

Would this system be useful as a clock device?

Applications of harmonic oscillators

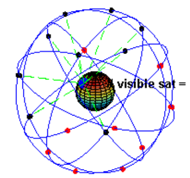
- Pendulum clocks -10s/day
- Crystal oscillators- Quartz watches - 0.1s/day
- Atomic clocks – Time standards based on atomic transition frequencies. -10^{-9}s/day

Clocks are important for navigation

Longitude: The True Story Of The Lone Genius Who Solved The Greatest Scientific Problem Of His Time

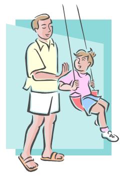
John Harrison

Global positioning satellites determine positioning using accurate clocks



Forced vibrations and resonance

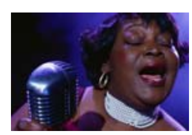
The periodic force puts energy into the system



The push frequency must be at the same frequency as the frequency of the swing.
The driving force is in resonance with the natural frequency.

Resonance

When the driving oscillations has a frequency that matches the oscillation frequency of the standing waves in the system then a large amount of energy can be put into the system.



Coupled Oscillations

When two oscillators are coupled by an interaction, energy can be transferred from one oscillator to another.

The rate of energy transfer is faster when the two oscillators are in resonance.