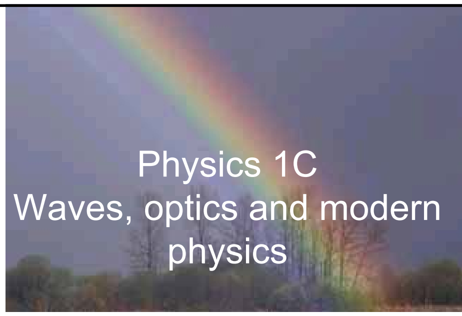


Physics 1C
Waves, optics and modern physics

Instructor: Melvin Okamura

email: mokamura@physics.ucsd.edu

Course Information

Course Syllabus on the web page http://physics.ucsd.edu/students/courses/spring2010/physics1c

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

TA: Parit Agarwal
Office: TBA
Office Hrs: TBA

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

Class Schedule

- **Lectures**
  - Tu, Thu. 11:00-12:20 pm York Hall 2722
- **Quizzes**
  - Third Thu (see schedule)
  - 11:00-12:200 pm York Hall 2722
- **Problem Session**
  - Wed. 8:00-9:50 York 2622

Grades

- Quizzes (3) will be held on Thu 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

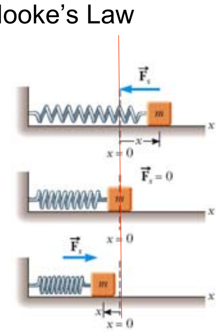
- Time for oscillations is independent of the amplitude of the oscillation.
- Useful as a timing device.

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

Hooke's Law

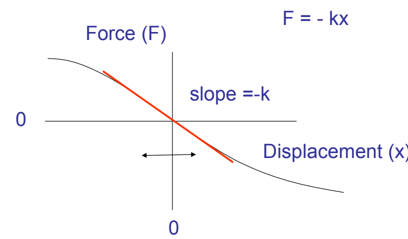
$$\vec{F} = -k\vec{x}$$

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



Equilibrium position

Hooke's Law

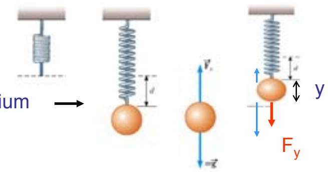


Hooke's law almost always holds for small displacements

Vertical direction

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

Equilibrium position →

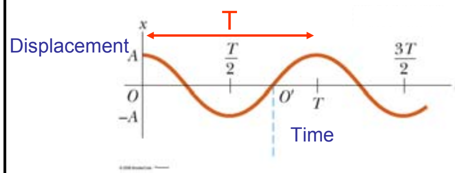


The force on the object is proportional to the displacement from the equilibrium position.

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

Hooke's Law is obeyed.

Description of Simple Harmonic Motion



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

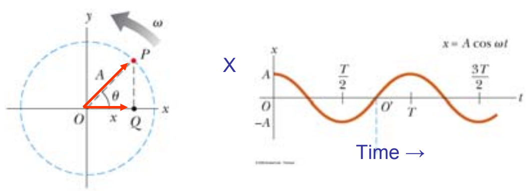
Amplitude - A (maximum displacement, m)

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.

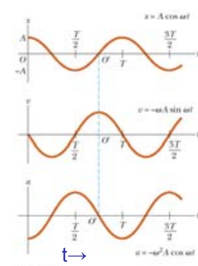
$$x = A\cos(\theta) = A\cos(\frac{2\pi}{T}t) = A\cos(2\pi ft) = A\cos(\omega t)$$

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.

Harmonic motion

http://www.animations.physics.unsw.edu.au/jw/SHM.htm

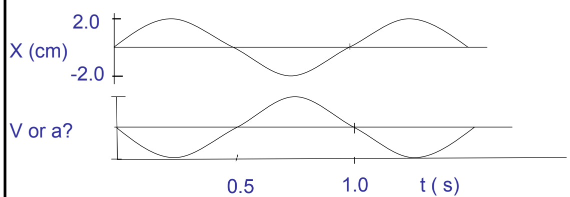
clip from University of New South Wales, School of physics.

Example

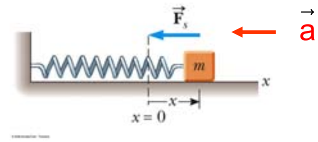
A mass on a spring is oscillating with a period of 0.5 s and amplitude of 2.0 cm.

What is the frequency?
What is the angular frequency?
What is the maximum speed?
What is the maximum acceleration?

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 $\vec{F}_s = m\vec{a}$



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

For sinusoidal motion.

$$F_s = -kx = -kA\cos\omega t$$

$$ma = -m\omega^2 A\cos\omega t$$

This gives

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

The frequency depends on k and m.

Frequency of the mass on a spring

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

Frequency increases with increasing k

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

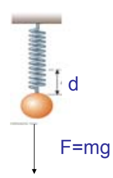
Frequency decreases with increasing m

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

Period changes in the opposite way.

Example

A 10 g mass is placed on a light spring displacing it by 5 cm. Calculate the oscillation frequency.



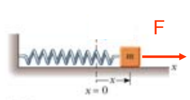
$$k = \frac{F}{d} = \frac{mg}{d} = \frac{(10x10^{-3}kg)(9.8m/s^2)}{5x10^{-2}m} = 1.96N/m$$

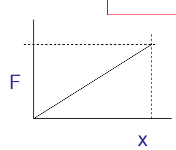
$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{1.96N/m}{10x10^{-3}kg}} = 2.22Hz$$

Energy

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

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



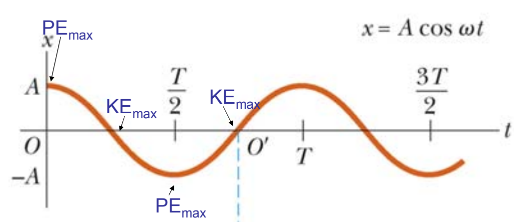


Work = $F_{average}$ x

$F_{average}$ =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



$$PE_{max} = \frac{1}{2}kA^2$$

$$KE_{max} = \frac{1}{2}mv^2_{max}$$

$$KE_{max} = PE_{max}$$

Example

A 10 g mass on a spring oscillates with an amplitude of 3 cm with a frequency of 2 Hz. Find the energy in the system.

A=3 cm

m=10 g

f=2 Hz

use PE_{max} $E = PE_{max} = \frac{1}{2}kA^2$

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

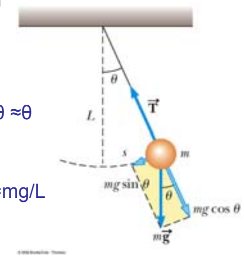
$k = 4\pi^2 f^2 m$

$E = \frac{1}{2}4\pi^2 f^2 m A^2 \quad = \frac{1}{2}4\pi^2(2s^{-1})^2(10x10^{-3}kg)(3x10^{-2}m)^2$

E=7.1x10^{-4} J

Pendulum

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



$F = -mg\sin\theta$

$F = -mg\theta$ for small θ, sinθ ≈θ

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

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

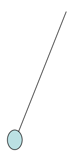
$\omega = \sqrt{\frac{k}{m}}$ then becomes

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

The period is dependent on L but independent of m

Example

A pendulum has a length of 1.0 m. Find the period of oscillation.



L=1.0 m

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

$T = 2\pi\sqrt{\frac{1.0m}{9.8m/s^2}} = 2.00s$

Question

How does the period of a pendulum depend on L?

How does the period depend on M?

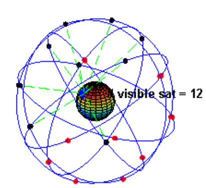
How does the period depend on amplitude?

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

Global positioning satellites determine positioning using accurate clocks



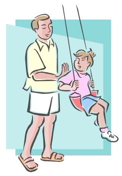
distances determined by elapsed time x speed of light

$d = c\Delta t$

speed of light c=3x10^8 m/s (error of 1ns -> error of 1foot.)

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.