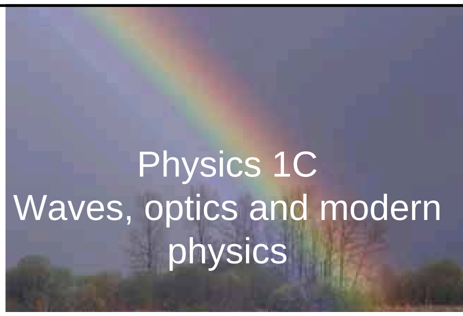


Physics 1C
Waves, optics and modern physics

Instructor: Melvin Okamura

email: mokamura@physics.ucsd.edu

Course Information

Course Syllabus on the web page http://physics.ucsd.edu/students/courses/Winter2010/physics1c

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

TA: Anthony Hopp, <ahopp@physics.ucsd.edu>
Office: TBA
Office Hrs: TBA

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

Class Schedule

- **Lectures**
  - Mon., Wed., Fri. 3:00-3:50 pm York Hall 2622
- **Quizzes**
  - Alternate Fridays
  - 3:00-3:50 pm York 2622
- **Problem Sessions**
  - Thu. 8:00-9:20 pm Center 214

Grades

- Quizzes (4) will be held on alternate Fri. 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 3 out of 4 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 course 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.
- Physical Optics
  - Interference, diffraction, polarization
- Quantum Mechanics
  - Quantum mechanics, atoms, molecules, transistors, lasers
- Nuclear Physics
  - Radioactivity, nuclear energy

1.1 Simple harmonic motion (SHM)

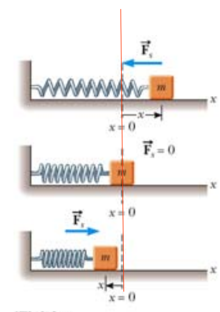
- Time for oscillations is independent of the amplitude of the oscillation.
- Useful as a timing device.

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

Hooke's Law – restoring force proportional to displacement

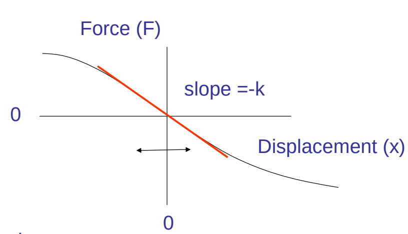
$$\vec{F} = -k\vec{x}$$

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



Equilibrium position

Hooke's Law



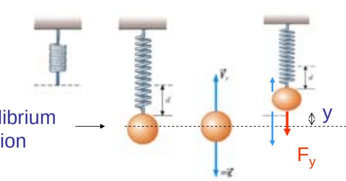
F = - kx

Hooke's law almost always holds for small displacements even if deviations occur at large displacements

Vertical direction

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

Equilibrium position

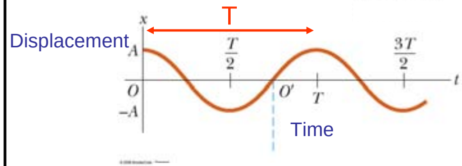


The force on the object is proportional to the displacement from the equilibrium position.

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

Hooke's Law is obeyed.

Description of Simple Harmonic Motion



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

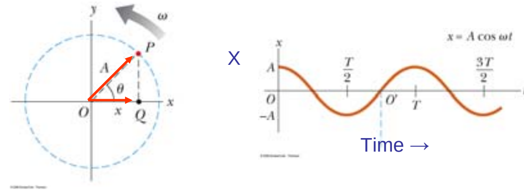
Amplitude - A (maximum displacement, m)

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.

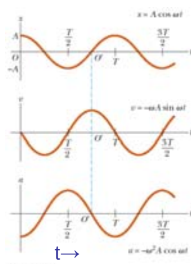
$$x = A\cos(\theta) = A\cos(\frac{2\pi}{T}t) = A\cos(2\pi ft) = A\cos(\omega t)$$

displacement, velocity, acceleration

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

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

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



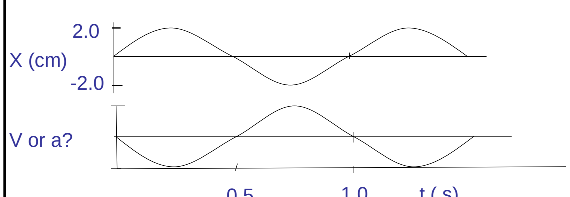
The magnitudes of v and a are multiplied by ω or ω^2 to preserve the units.

Example

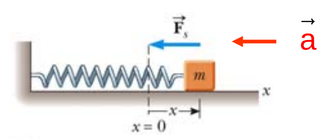
A mass on a spring is oscillating with a period of 0.5 s and amplitude of 2.0 cm.

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

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



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

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

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

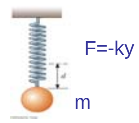
For sinusoidal motion.

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

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



How does the period depend on mass?

How does the period depend on the force constant?

How does the period depend on the amplitude?

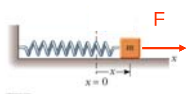
Demo

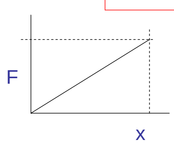
Find the force constant of a spring and calculate the oscillation frequency.

Energy

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

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





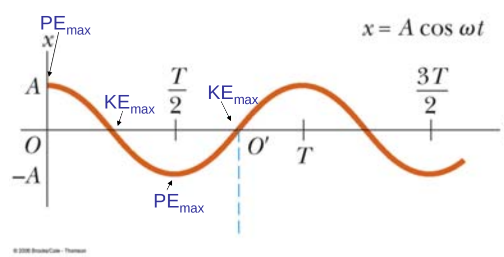
Work = $F_{average}$ x

$F_{average}$ =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 s for small displacements.

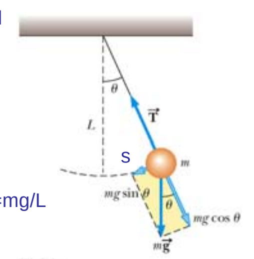
$$F = -mg\sin\theta$$

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

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

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

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



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

The period is dependent on L but independent of m

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 error
- 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