Simple Harmonic Motion

Syll. Statements:
Topic 4: 4.1.1-4.3.6

Oscillations

- Motion is repetitive (***Periodic***) and the oscillating body moves back and forth around an equilibrium position.
- **Period**: The time required for one full oscillation
  - We will focus on constant periods…
- What are some examples of oscillating bodies/systems?

Video Demo 1: Hooke's Law

- What is the relationship between the displacement of the spring and the force applied to the spring?
- What characteristics of the spring will affect this?
- **Hooke's Law:** up to its elastic limit, a spring will experience a displacement that is proportional to the force applied to the spring.

$$F = -kx$$

More on springs…

- **Restoring Force**:
  - the tension in the spring that works to bring a mass back to its rest position (equilibrium position).
  - The restoring force is the reaction force to any applied force (i.e. the weight of something hanging from the spring)
- This is the force that causes a mass to accelerate around its rest position when it has experienced a displacement away from equilibrium.
- http://webphysics.davidson.edu/applets/animator4/demo_hook.html
- http://webphysics.davidson.edu/mazur/ch9/ex9_3.html

Simple Harmonic Motion

- A special case of periodic oscillations that can be described by analyzing the forces involved in the motion

http://www.walter-fendt.de/ph14e/springpendulum.htm

- Hooke's law can be rewritten as… $ma = -kx$
- We are going to define **angular frequency** as: $\omega = \sqrt{\frac{k}{m}}$
- Angular frequency also has units of Hertz (s^{-1})

Defining relation for SHM:

$$a = -\omega^2 x$$

- "Simple harmonic motion takes place when a particle that is disturbed away from its *fixed* equilibrium position experiences an *acceleration that is proportional and opposite to its displacement*" (*from the IB Physics text by Tsokos)*
  - Two requirements for SHM:
    - Must have a fixed equilibrium point
    - Acceleration, when displaced, must be proportional to the amount of displacement

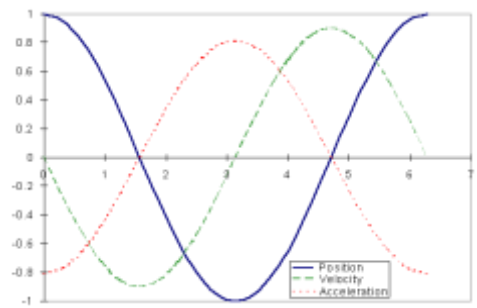
SHM--mathematics

- By using calculus *(which we're not going to do…just trust me on the result!),* the defining relationship becomes one that we can put in terms of the angular frequency, the time that has passed, the amplitude of the displacement, and the "phase shift"

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

- A = amplitude
- t = time
- ϕ = phase shift
- ω = angular frequency

- **Amplitude:** the maximum displacement away from the equilibrium (rest) position.
  - **This occurs** when the value of the cosine function is equal to 1
- **ϕ = Phase Shift:** recorded in radians; gives an indication of the displacement at t = 0 s.
  - *See diagram on next slide…*
- Phase difference: $\Delta\phi = |\phi_1 - \phi_2|$



Simple Pendulum…

- *For small angles*, the behavior of a pendulum can be approximated using the principles of Simple Harmonic Motion
  - Period of a pendulum can be found with:

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

Sample calculations

- Calculate the length of a pendulum that has a period equal to 1.00 s.

Energy in SHM

- How is elastic potential energy calculated?
- How is kinetic energy calculated?
- Sketch a graph showing the potential energy and the kinetic energy of a mass on a spring; also include its total energy.

Determining the velocity of the mass on the spring…

- When will maximum velocity occur?

Sample calculation—SHM

- A particle of mass 0.50 kg undergoes SHM with angular frequency $\omega = 9.0\ s^{-1}$ and amplitude 3.0 cm. For this particle, determine:
  - The maximum velocity
  - The velocity and acceleration when the particle has displacement 1.5 cm and moves towards the equilibrium position from its initial position at x = 3.0 cm.
  - The total energy of the motion

Pre-lab:

- Design an experiment to test the effect of some variable on the period of a pendulum.

Lab Instructions:

- Once you've determined your problem question, your variables, and your materials, begin collecting data.
- This lab will be a full lab write-up: Design, DCP, and CE
- We will collect data today and part of tomorrow, if needed. We'll know by today…