Phys141 – Fri 11/11

TODAY: Oscillations (Ch 15) +Waves (Ch 16)

Harmonic oscillation

Show that the ansatz solves the equation

Harmonic oscillation $\frac{d^2\theta}{dt^2} = -\omega^2\theta$ $\theta = \theta_{max} \cos(\omega t + \phi)$

$\omega = \sqrt{\frac{g}{L}}$

FEATURES:

ω: angular frequency – related quantities are:

f=ω/2π frequency of oscillation
T=1/f Period of oscillation

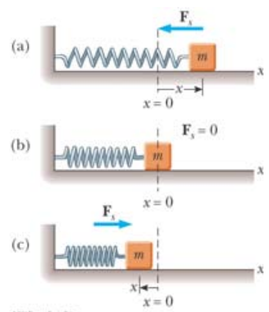
θ_{Max}: Amplitude of oscillation

ϕ: phase constant or the initial phase angle

Example 2: Spring-Mass System

A block of mass *m* is attached to a spring, the block is free to move on a frictionless horizontal surface

When the spring is neither stretched nor compressed, the block is at the ***equilibrium position*** *x* = 0



Note: Force pointed toward equilibrium position

Simple Harmonic Motion

The force described by Hooke's Law is the net force in Newton's Second Law

$$F_{\text{Hooke}} = F_{\text{Newton}}$$
$$-kx = ma_x$$

Acceleration $a_x = \frac{d^2x}{dt^2} = -\frac{k}{m}x$

$$\omega^2 = \frac{k}{m}$$

$$\frac{d^2x}{dt^2} = -\omega^2 x$$

Which function satisfies this differential equation?

Simple harmonic motion

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

A, ω, ϕ are all constants

A amplitude of the motion

ω angular frequency $\omega = \sqrt{\frac{k}{m}}$

frequency $f = \frac{1}{T} = \frac{\omega}{2\pi}$

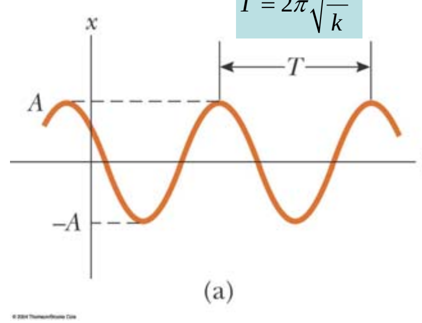
Period $T = 2\pi\sqrt{\frac{m}{k}}$

ϕ phase constant or the initial phase angle

Graphical Representation

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

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



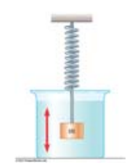
When is max amplitude reached?
-> $\cos(\omega t + \phi) = 1$ -> $\omega t + \phi = 0, 2\pi, 4\pi, 6\pi, \ldots$

Phase constant (initial phase angle) determined by initial conditions

Damped Oscillation

In many real systems, energy is dissipated into heat (e.g. due to viscosity) i.e. non-conservative forces are present:

- **Viscous force:** **R** = - *b* **v** =-*b* dx/dt
  - *b* is called the ***damping coefficient***



Spring oscillation without viscous force

$$ma_x = m\frac{d^2x}{dt^2} = -kx$$

With viscous force $m\frac{d^2x}{dt^2} = -kx - b\frac{dx}{dt}$

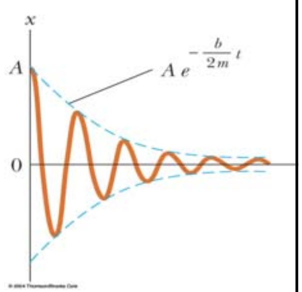
Damped Oscillation, equations

For small b, the equation can be solved as:

$$x(t) = Ae^{-\frac{b}{2m}t}\cos(\omega t + \phi)$$

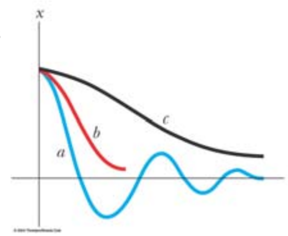
The angular frequency will be smaller than without the retardation

$$\omega = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$$



Types of Damping

- Graphs of position versus time for
  - (a) an underdamped oscillator
  - (b) a critically damped oscillator
  - (c) an overdamped oscillator
- For critically damped and overdamped there is no angular frequency

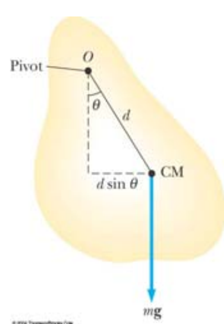


Has to be > 0 for oscillations

$$\omega = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$$

Physical Pendulum

- Mass NOT concentrated in one point
- The gravitational force provides a torque about an axis through *O*
- The magnitude of the torque is *mgd* sin θ
- *I* is the moment of inertia about the axis through *O*



Physical Pendulum

From Newton's Second Law (torque version)

$$-mgd\sin\theta = I\frac{d^2\theta}{dt^2}$$

Note: The gravitational force produces a restoring force

Assuming θ is small, this becomes

$$\frac{d^2\theta}{dt^2} = -\left(\frac{mgd}{I}\right)\theta = -\omega^2\theta \longrightarrow \omega = \sqrt{\frac{mgd}{I}}$$

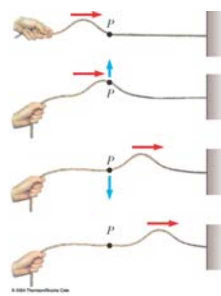
-> A physical pendulum can be used to measure the moment of inertia of a flat rigid object

Chapter 16 - Waves

- There are two main types of waves
  - Mechanical waves
    - Some physical medium is being disturbed
    - The wave is the propagation of a disturbance through a medium
  - Electromagnetic waves (next semester)
    - No medium required
    - Examples are light, radio waves, x-rays

Example: Pulse on a Rope

- flick one end of a rope under tension
- A single bump is formed and travels along the rope
  - The bump is called a **pulse**

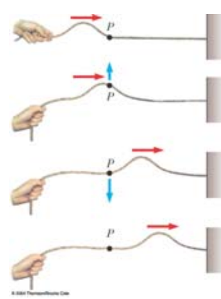


Pulses and Waves

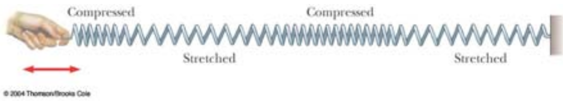
- rope is the "medium" through which **pulse** travels
- The pulse has a definite speed of propagation along the medium
- A continuous flicking of the rope would produce a periodic disturbance which would form a **wave**
- Waves/ pulses
  - transfer energy over a distance
  - Matter is **not** transferred over a distance

Transverse Wave

- A traveling wave or pulse that causes the elements of the disturbed medium to move **perpendicular** to the direction of propagation is called a **transverse wave**
- particle motion
  -> blue arrow
- propagation direction
  -> red arrow

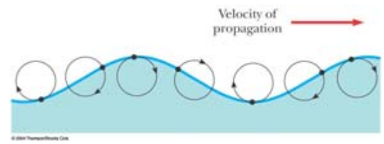


Longitudinal Wave



- A traveling wave or pulse that causes the elements of the disturbed medium to move parallel to the direction of propagation is called a **longitudinal wave**
- The displacement of the coils is parallel to the propagation

Complex Waves



- Some waves exhibit a combination of transverse and longitudinal waves
- Surface water waves are an example