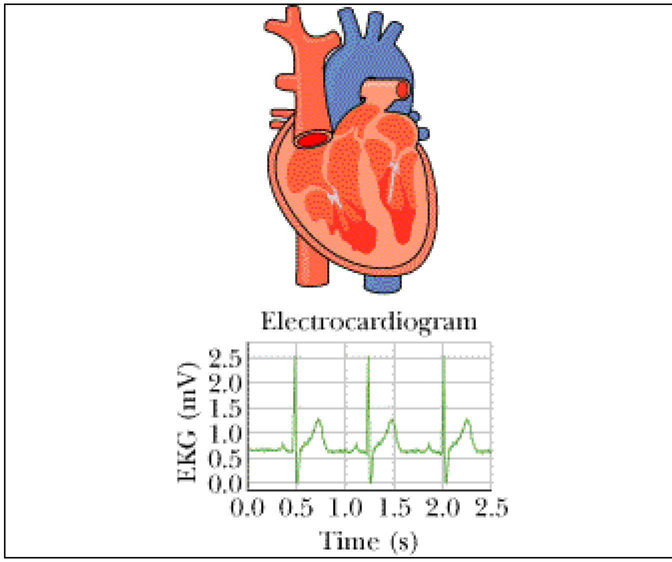
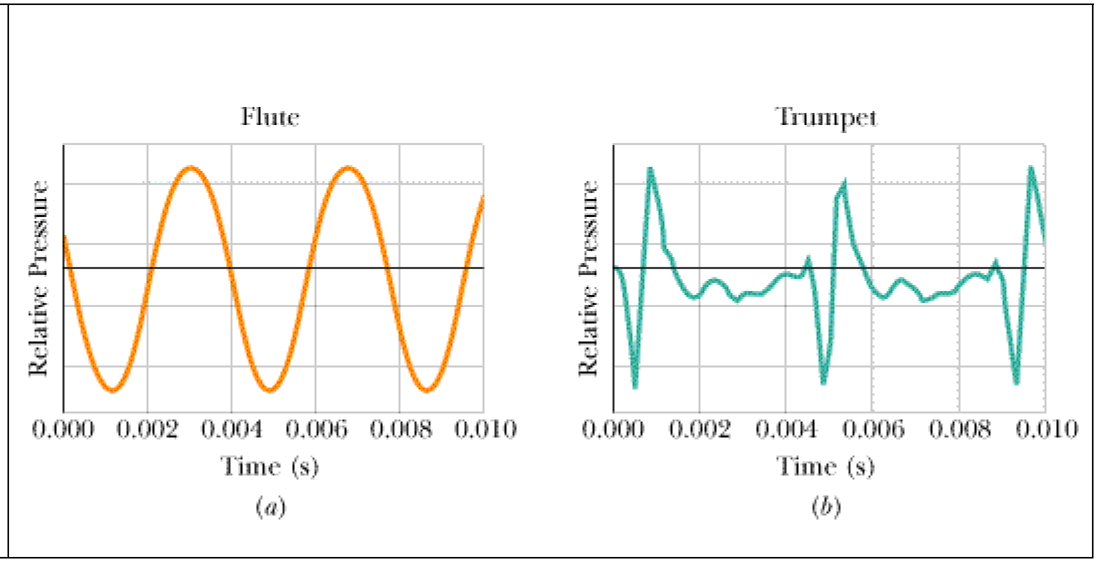
Chapter 16 Oscillations

1. Periodic Motion
2. Simple Harmonic Motion
   - Displacement
   - Velocity
   - Acceleration
   - Force

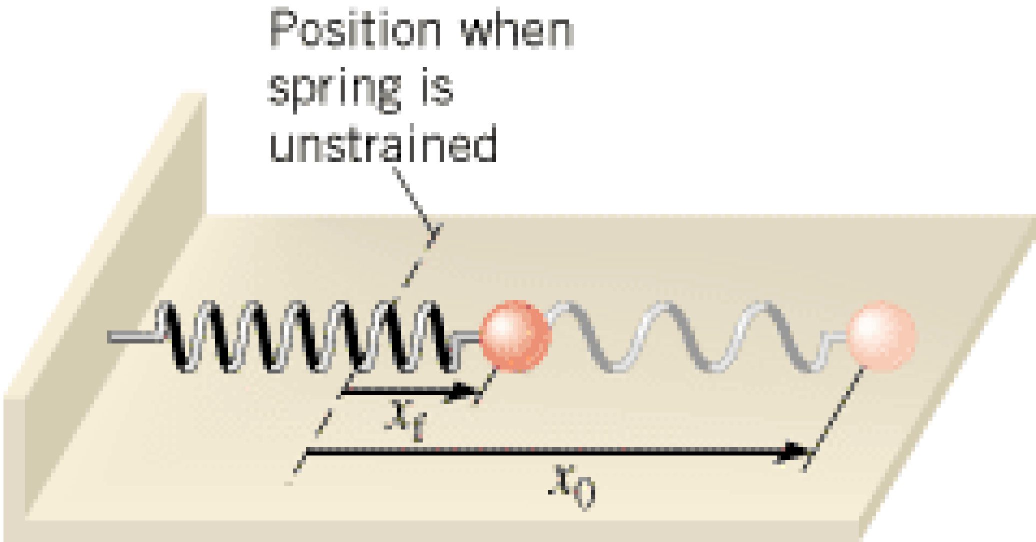
Periodic Motion

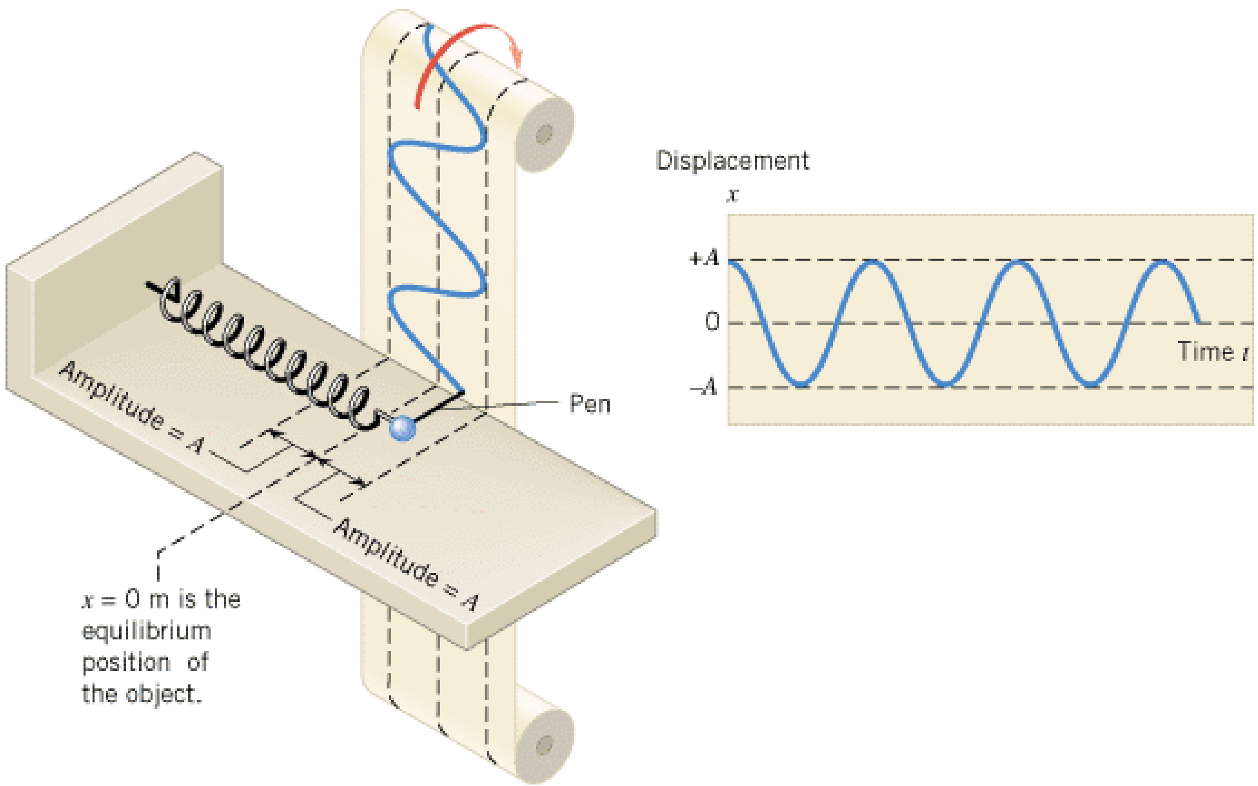




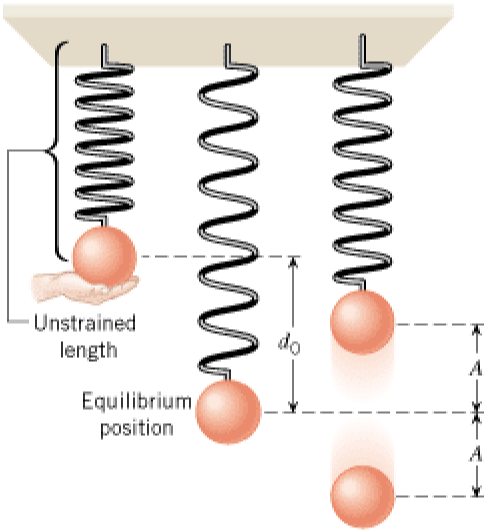
- Any measurable quantity that repeats itself at regular time intervals is defined as undergoing **periodic** motion.
- If the periodic variation of a physical quantity over time has the shape of a sine (or cosine) function, we call it a **sinusoidal oscillation or simple harmonic motion.**
- **Any periodic** motion is superposition of **simple harmonic motions.**

Simple Harmonic Motion



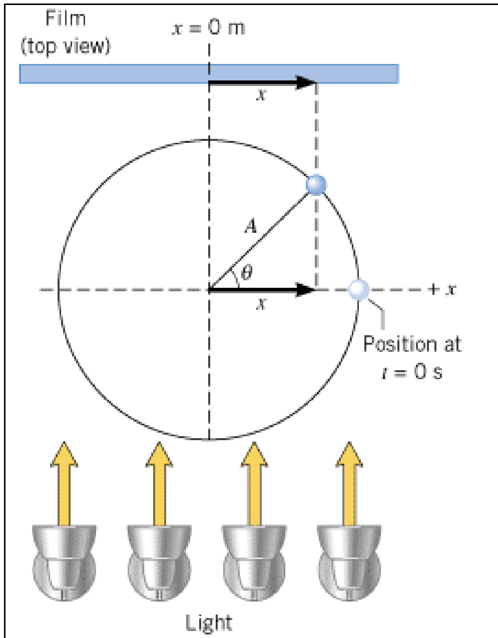


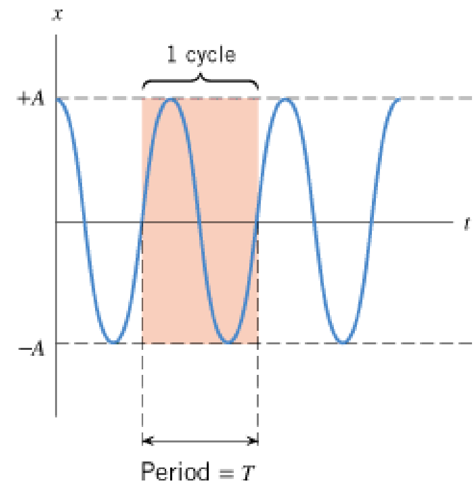
The maximum excursion from equilibrium is the ***amplitude*** *A* of the motion



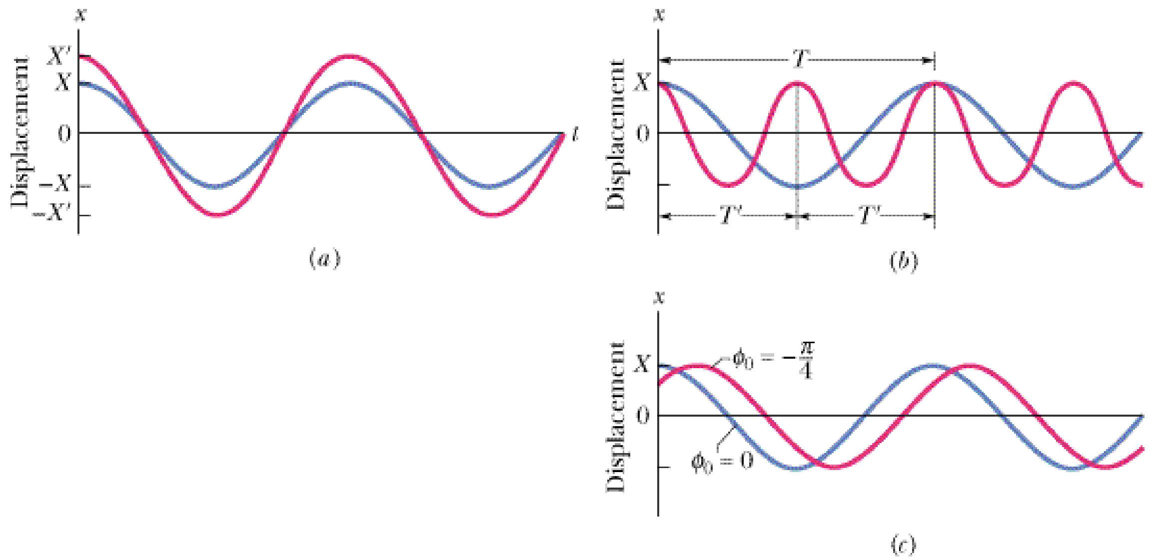
The weight of an object on a vertical spring stretches the spring by an amount d_0. Simple harmonic motion of amplitude A occurs with respect to the equilibrium position of the object on the stretched spring.

Displacement:





- $x = A\cos\theta = A\cos\omega t$
- The ***period T*** is the time required for one complete motional cycle.
- The ***frequency f*** of the motion is the number of cycles of the motion per second (unit is: 1 cycle/second=1 Hz).
- Frequency and period are related according to: $f = \dfrac{1}{T}$
- ***Angular frequency ω:*** $\omega = \dfrac{2\pi}{T} = 2\pi f \;\; (\omega \text{ in rad/s})$



Displacement at time t

Angular frequency

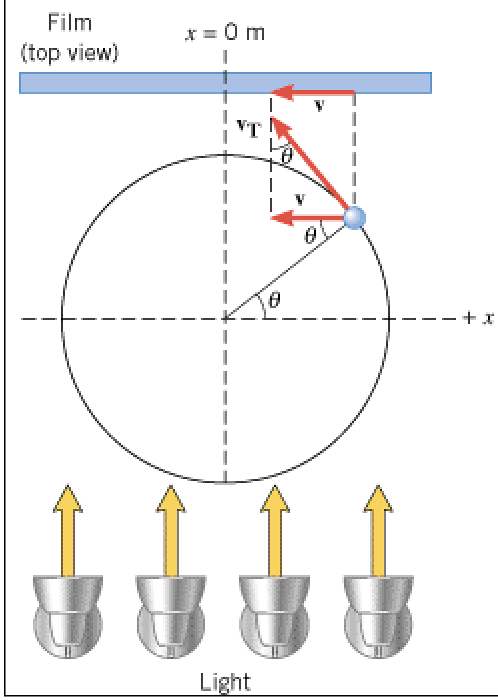
Initial phase (or phase constant)

$$x(t) = X\cos(\omega t + \phi_0)$$

Amplitude (maximum displacement)

Time-dependent phase

VELOCITY



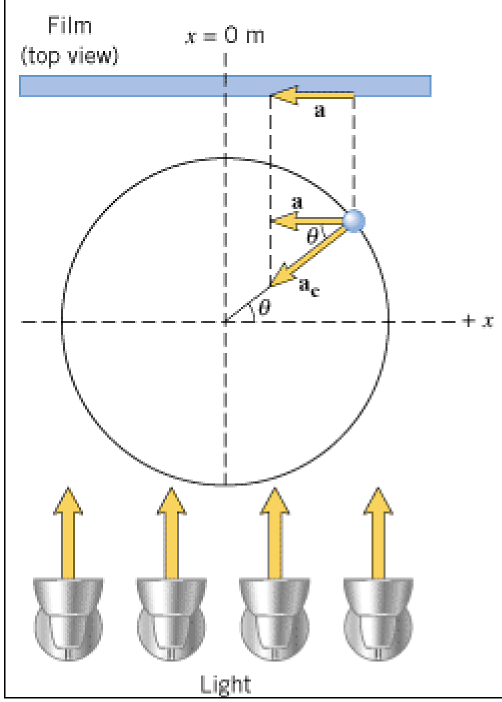
- The velocity in simple harmonic motion is given by

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

- The maximum magnitude of velocity is

$$v_{max} = A\omega \quad (\omega \text{ in rad / s})$$

ACCELERATION



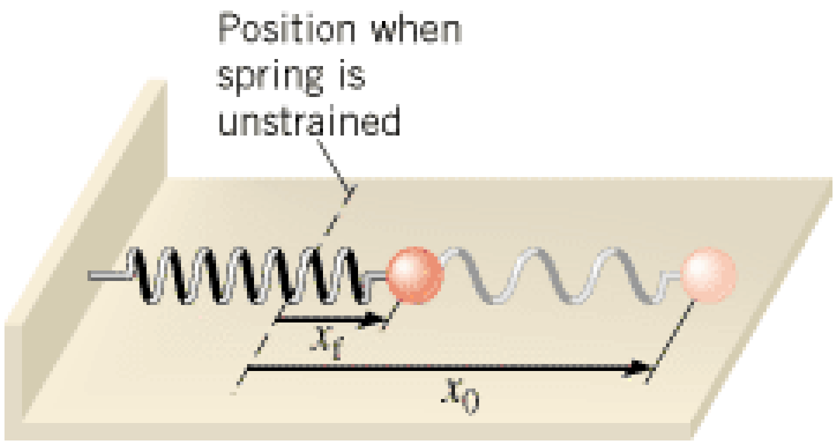
- The acceleration in simple harmonic motion is

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

- The maximum magnitude of the acceleration is

$$a_{max} = A\omega^2 \quad (\omega \text{ in rad / s})$$

Force on an object in Simple Harmonic Motion



$$F = ma = -m\omega^2 x$$

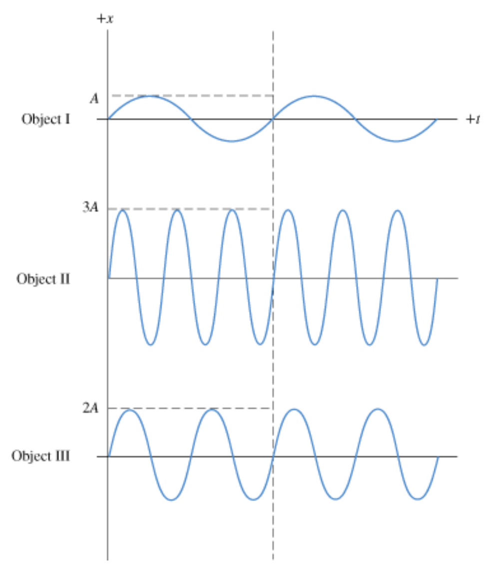
$$F = -kx$$

Where K is a constant

Any object under a force of $F = -kx$ will be in simple harmonic motion. This force is called restoring force.

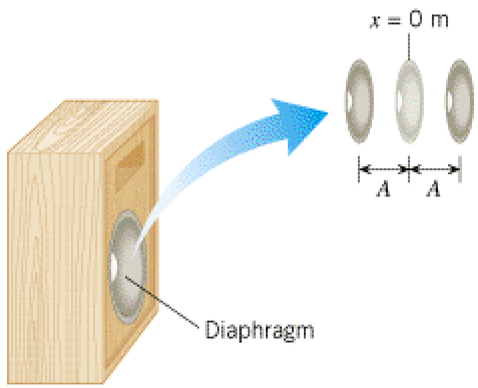
Check Your Understanding 2

The drawing shows plots of the displacement x versus the time t for three objects undergoing simple harmonic motion. Which object, I, II, or III, has the greatest maximum velocity?



Example 1 **The Maximum Speed of a Loudspeaker Diaphragm**

The diaphragm of a loudspeaker moves back and forth in simple harmonic motion to create sound, as in Figure. The frequency of the motion is $f = 1.0$ kHz and the amplitude is $A = 0.20$ mm. (a) What is the maximum speed of the diaphragm? (b) Where in the motion does this maximum speed occur? (c) What is the maximum acceleration of the diaphragm, and (d) where does this maximum acceleration occur?



Example 2

An 0.80-kg object is attached to one end of a spring, as in Figure, and the system is set into simple harmonic motion. The displacement *x* of the object as a function of time is shown in the drawing. With the aid of these data, determine (a) the amplitude *A* of the motion, (b) the angular frequency ω, (d) the speed of the object at $t = 1.0$ s, and (e) the magnitude of the object's acceleration at $t = 1.0$ s.