جامعة الملك عبدالعزيز
KING ABDULAZIZ UNIVERSITY

PHYS 203

Ch. 3

Oscillations

Chapter 3

Chapter Three

Oscillations

- ***Simple Harmonic Motion***
- ***Pendulums, Circular Motion***

Simple Harmonic Motion

Simple Harmonic Motion

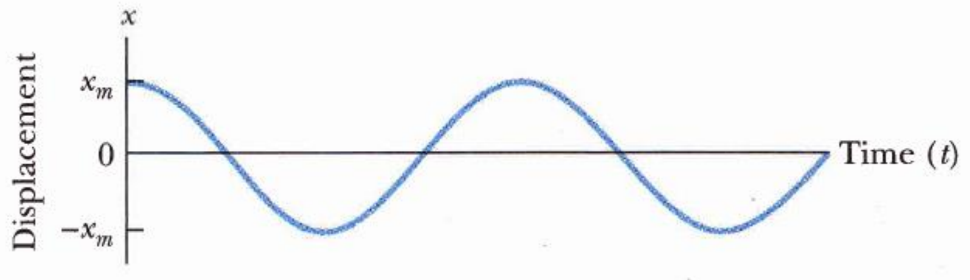
A particle moving repeatedly back and forth about the origin of an x axis.

One important property of oscillatory motion is its **frequency,** number of oscillations that are completed each second.

The symbol for frequency is f,

SI unit is the **hertz**

$$1 \text{ hertz} = 1 \text{ Hz} = 1 \text{ oscillation per second} = 1 \text{ s}^{-1}$$



Simple Harmonic Motion

Related to the frequency is the **period** T of the motion, which is the time for one complete oscillation

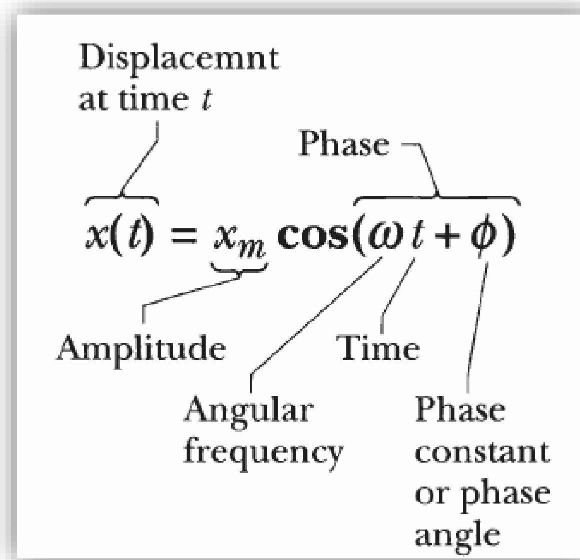
$$T = \frac{1}{f}.$$

The displacement x of the particle from the origin is given as a function of time by

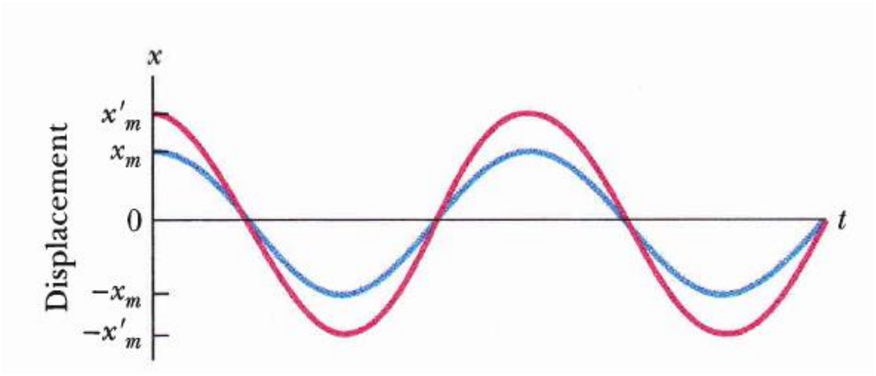
$$x(t) = x_m \cos(\omega t + \phi)$$

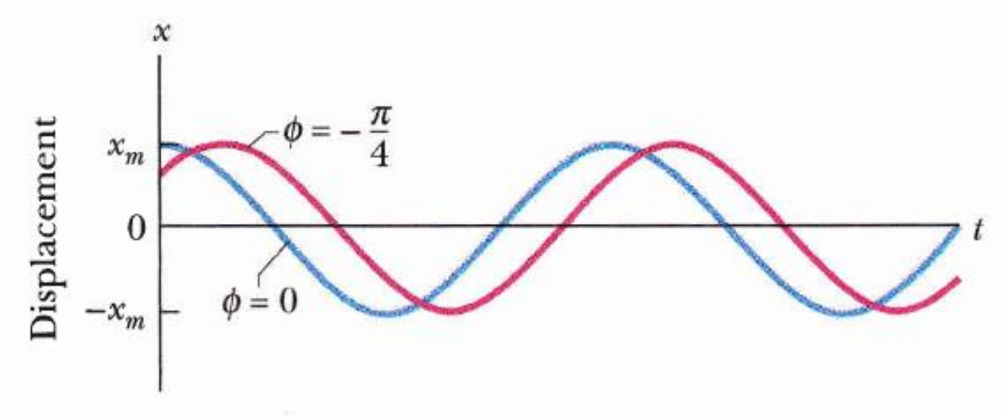
$$\omega = \frac{2\pi}{T} = 2\pi f.$$

SI unit of angular frequency is the radian per second.

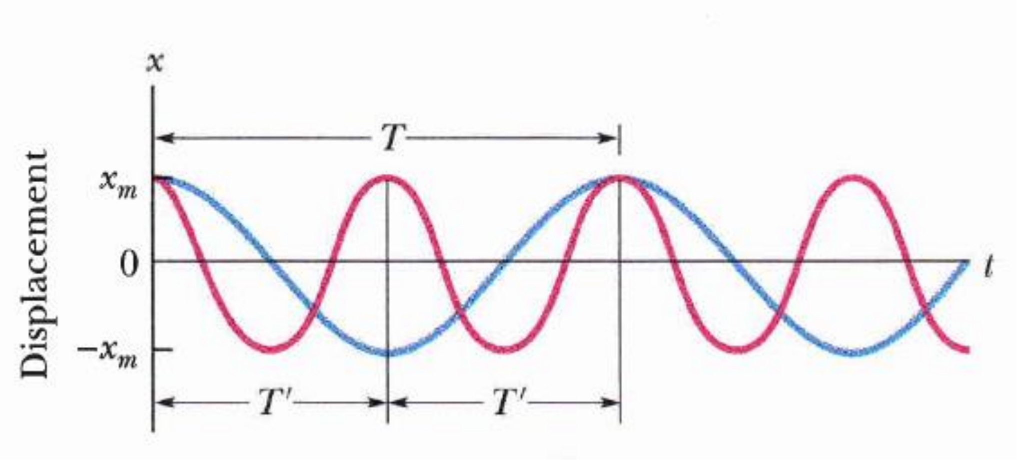


Simple Harmonic Motion





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



Simple Harmonic Motion

Example 1:

A particle is in simple harmonic motion with period T. At time t = 0 it is at the equilibrium point. At the times listed below it is at various points in its cycle. Which of them is farthest away from the equilibrium point?

Solution:

(B)

(A) $0.5T$
(B) $0.7T$
(C) T
(D) $1.4T$

Simple Harmonic Motion

Example 2:

A particle moves back and forth along the x axis from $x = -xm$ to $x = +xm$, in simple harmonic motion with period T. At time $t = 0$ it is at $x = +xm$. When $t = 0.75T$:

Solution:

(A)

(A) it is at $x = 0$ and is traveling toward $x = +xm$
(B) it is at $x = 0$ and is traveling toward $x = -xm$
(C) it is between $x = 0$ and $x = +xm$ toward $x = -xm$
(D) it is between $x = 0$ and $x = -xm$ toward $x = -xm$

Simple Harmonic Motion

Example 3:

An object attached to one end of a spring makes 20 complete vibrations in 10s. Its period is:

Solution:

(D)

(A) 2 Hz
(B) 0.5 Hz
(C) 2 s
(D) 0.5 s

Simple Harmonic Motion

Example 4:

Referring to Example 3, the frequency of an object is:

Solution:

(A)

(A) 2 Hz
(B) 0.5 Hz
(C) 2 s
(D) 0.5 s

Simple Harmonic Motion

Example 5:

Referring to Example 3, the angular frequency of an object is:

Solution:

(D)

(A) 0.79 rad/s
(B) 2.0 rad/s
(C) 6.3 rad/s
(D) 12.6 rad/s

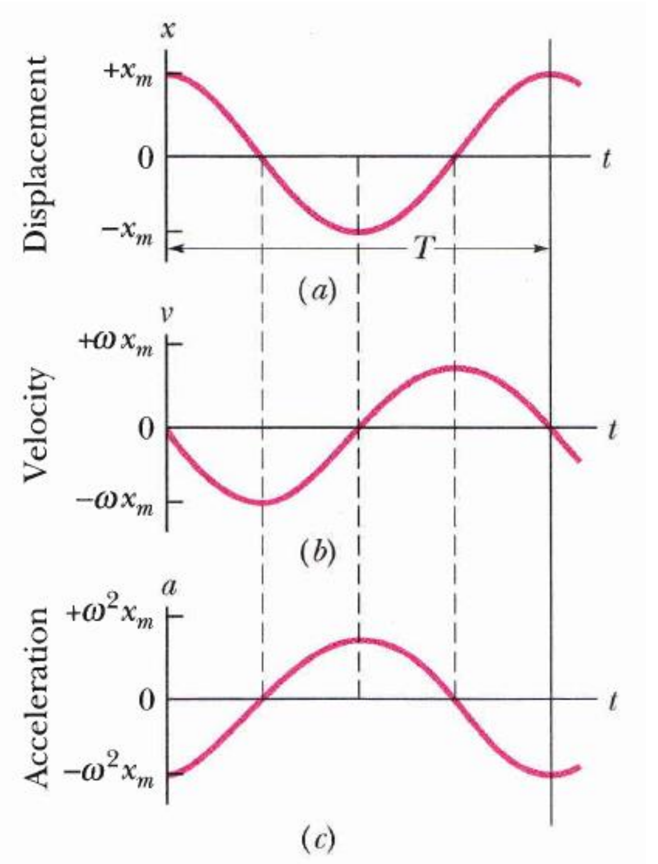
Simple Harmonic Motion

The Velocity of SHM

$$v(t) = \frac{dx(t)}{dt} = \frac{d}{dt}[x_m \cos(\omega t + \phi)]$$

$$v(t) = -\omega x_m \sin(\omega t + \phi)$$

ωx_m is called the **velocity amplitude** v_m.



Simple Harmonic Motion

Example 6:

A particle moves in simple harmonic motion according to $x = 2\cos(50t)$, where x is in meters and t is in seconds. Its maximum velocity is:

Solution:

(B)

(A) $100 \sin(50t)$ m/s
(B) 100 m/s
(C) $100 \cos(50t)$ m/s
(D) 200 m/s

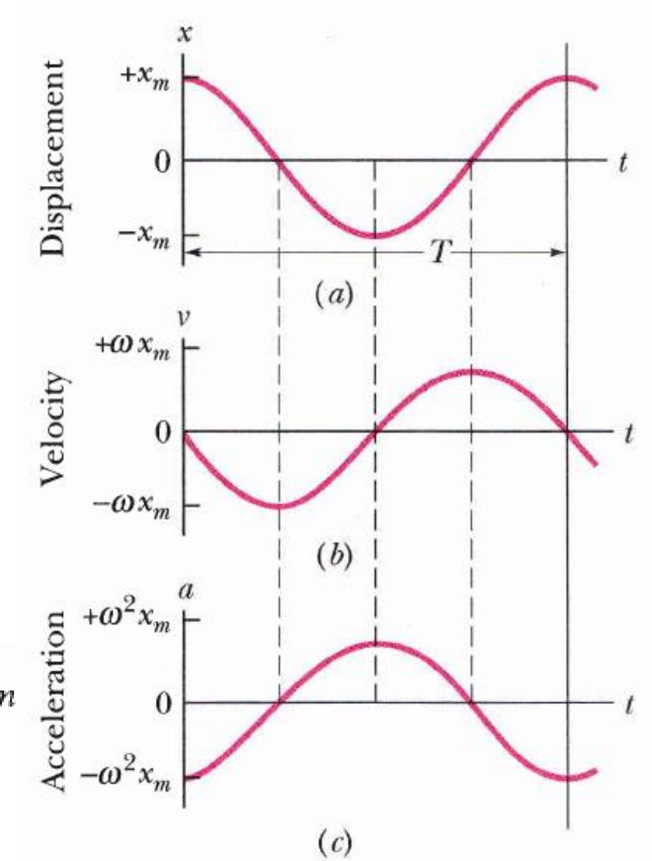
Simple Harmonic Motion

The Acceleration of SHM

$$a(t) = \frac{dv(t)}{dt} = \frac{d}{dt}[-\omega x_m \sin(\omega t + \phi)]$$

$$a(t) = -\omega^2 x_m \cos(\omega t + \phi)$$

$\omega^2 x_m$ is called the **acceleration amplitude** a_m



Simple Harmonic Motion

In SHM, the acceleration a is proportional to the displacement x but opposite in sign, and the two quantities are related by the square of the angular frequency ω.

$$a(t) = -\omega^2 x(t).$$

Example 7:

An oscillatory motion must be simple harmonic if:

Solution:

(D)

(A) the amplitude is small
(B) the potential energy is equal to the kinetic energy
(C) the motion is along the arc of a circle
(D) the acceleration varies sinusoidally with time

Simple Harmonic Motion

Example 8:

The maximum acceleration of a platform that oscillates at amplitude 2.20 cm and frequency 6.60 Hz is:

Solution:

(C)

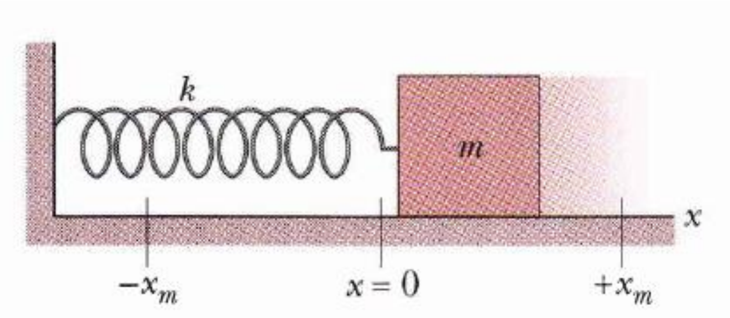
(A) 19.6 m/s^2
(B) 26.3 m/s^2
(C) 37.8 m/s^2
(D) 46.1 m/s^2

Simple Harmonic Motion

The Force Law for Simple Harmonic Motion

Simple harmonic motion is the motion of a particle when the force acting on it is proportional to the particle's displacement but in the opposite direction.

The angular frequency ω of the simple harmonic motion of the block is related to the spring constant k and the mass m of the block

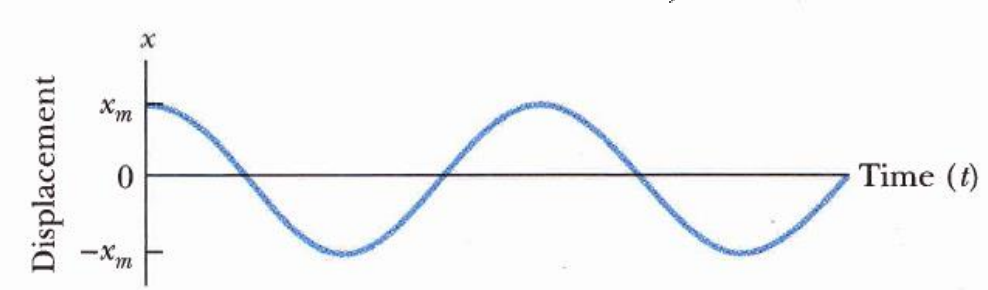


$$\omega = \sqrt{\frac{k}{m}}$$

$$F = -kx,$$

the **period**

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



Simple Harmonic Motion

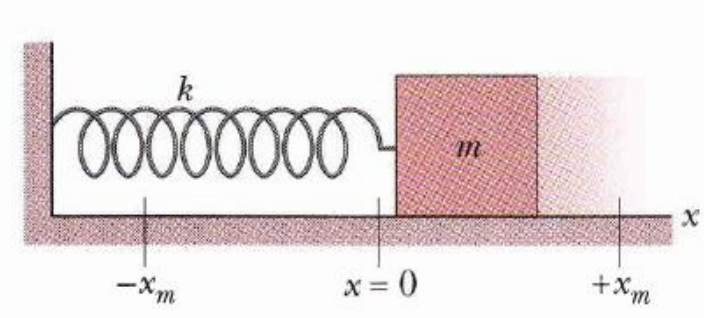
Example 9:

A block whose mass m is 680 g is fastened to a spring whose spring constant k is 65 N/m. The block is pulled a distance x = 11 cm from its equilibrium position at x = 0 on a frictionless surface and released from rest at t = 0. The frequency is:

Solution:

(C)

(A) 3.27 Hz
(B) 2.09 Hz
(C) 1.56 Hz
(D) 0.48 Hz



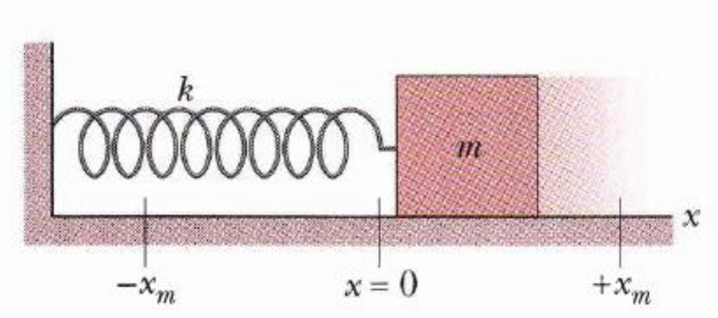
Example 10:

Referring to Example 9, the period is:

Solution:

(A)

(A) 0.64 s
(B) 1.37 s
(C) 2.90 s
(D) 3.81 s



Simple Harmonic Motion

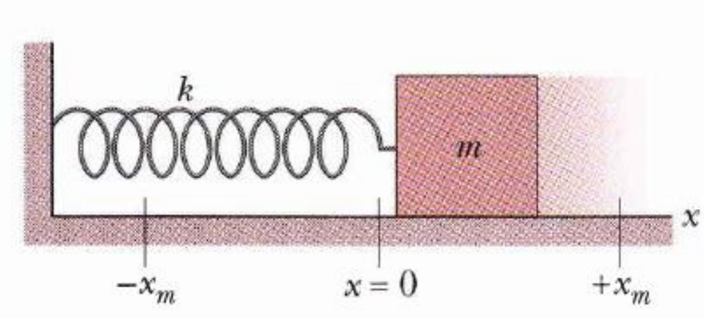
Example 11:

Referring to Example 9, the amplitude of the oscillation is:

Solution:

(D)

(A) 8 cm
(B) 9 cm
(C) 10 cm
(D) 11 cm



Simple Harmonic Motion

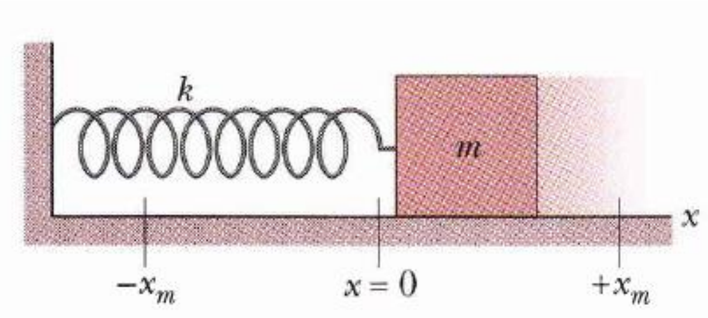
Example 12:

Referring to Example 9, the maximum speed is:

Solution:

(A)

(A) 1.1 m/s
(B) 2.2 m/s
(C) 3.3 m/s
(D) 4.4 m/s



Simple Harmonic Motion

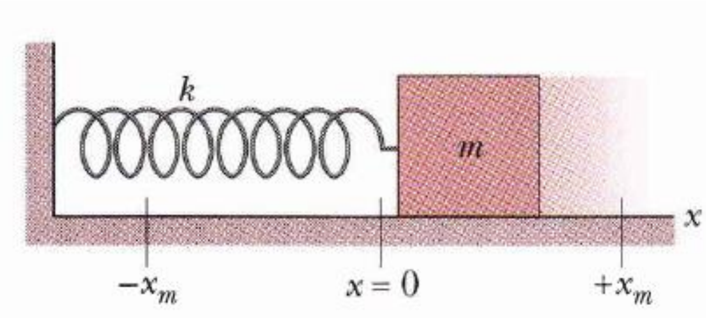
Example 13:

Referring to Example 9, the maximum acceleration is:

Solution:

(B)

(A) 10 m/s^2
(B) 11 m/s^2
(C) 12 m/s^2
(D) 13 m/s^2



Simple Harmonic Motion

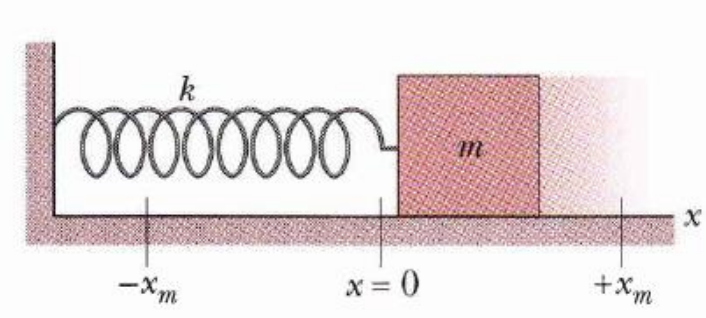
Example 14:

Referring to Example 9, the phase constant for the motion is:

Solution:

(A)

(A) 0 rad
(B) 3.14 rad
(C) 6.28 rad
(D) 9.42 rad



Simple Harmonic Motion

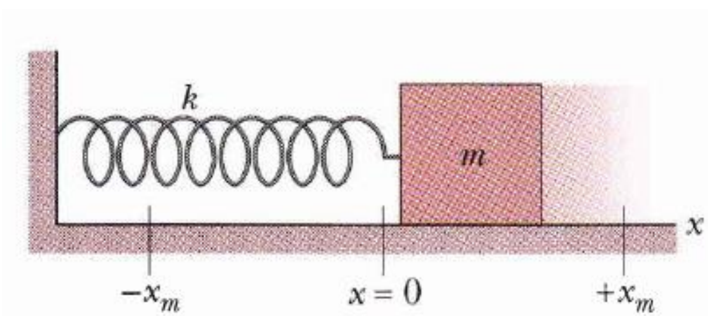
Example 15:

Referring to Example 9, the displacement function $x(t)$ for the spring–block system is:

Solution:

(C)

(A) 0.11 cos(9.8*x*)
(B) 0.11 cos(9.8y)
(C) 0.11 cos(9.8t)
(D) 0.11 cos(9.8z)



Example 16:

A 0.12 kg body undergoes simple harmonic motion of amplitude 8.5 cm and period of 0.20 s. The magnitude of the maximum force acting on it is

Solution:

(B)

(A) 7.30 N
(B) 10.1 N
(C) 16.3 N
(D) 23.6 N

Simple Harmonic Motion

Example 17:

Referring to Example 16, if the oscillation produced by a spring, the spring constant is:

Solution:

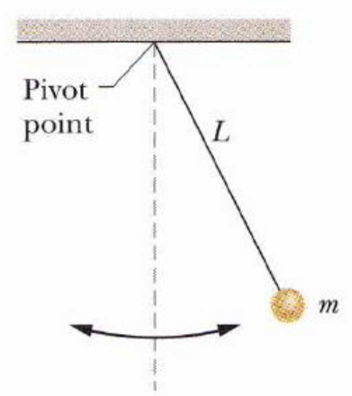
(D)

(A) 205.7 N/m
(B) 197.8 N/m
(C) 160.5 N/m
(D) 118.4 N/m

Pendulums, Circular Motion

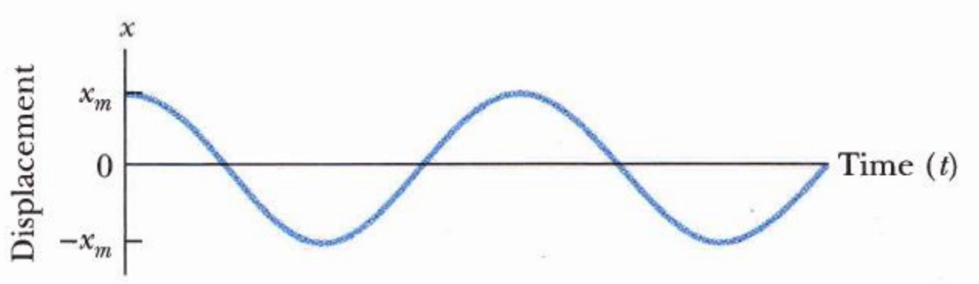
Pendulums

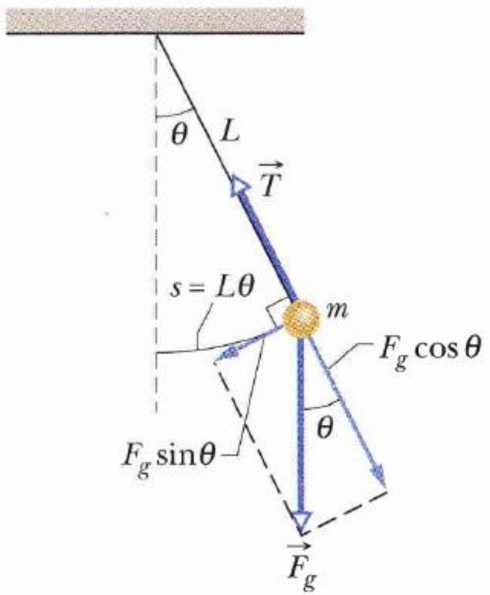
The motion of a *simple pendulum swinging through only small angles* is approximately SHM.



The period of the pendulum may be written as

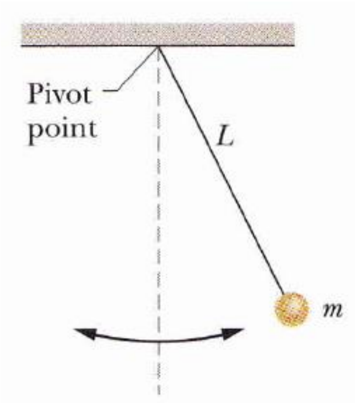
$$T = 2\pi\sqrt{\frac{I}{mgL}}.$$





Pendulums, Circular Motion

where I rotational inertia of the pendulum



$$I = mL^2$$

$$T = 2\pi\sqrt{\frac{mL^2}{mgL}}.$$

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

(simple pendulum, small amplitude).

Pendulums, Circular Motion

Example 18:

A simple pendulum swing about a pivot point at one end, at distance $L_0 = 9.8$ m. The period of the oscillation T is:

Solution:

(C)

(A) 2.19 s
(B) 3.46 s
(C) 6.28 s
(D) 9.41 s