

Physics 101: Lecture 20 Elasticity and Oscillations

Today's lecture will cover Textbook Chapter 10.5-10.10



Tuned mass damper
(pendulum) in Taipei 101

Review Energy in SHM

- A mass is attached to a spring and set to motion. The maximum displacement is $x=A$

→ Energy = $U + K = \text{constant!}$

$$= \frac{1}{2} k x^2 + \frac{1}{2} m v^2$$

→ At maximum displacement $x=A$, $v = 0$

$$\text{Energy} = \frac{1}{2} k A^2 + 0$$

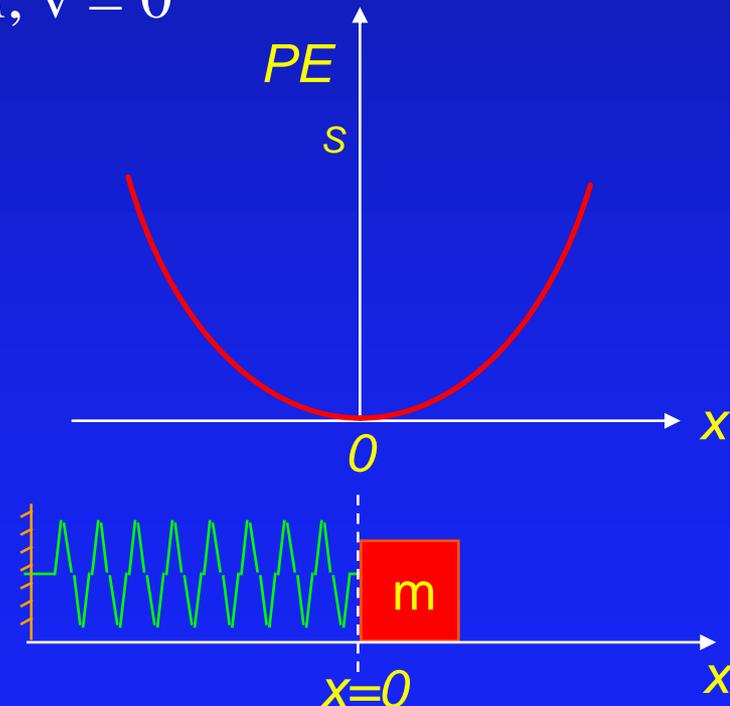
→ At zero displacement $x = 0$

$$\text{Energy} = 0 + \frac{1}{2} m v_m^2$$

$$\frac{1}{2} k A^2 = \frac{1}{2} m v_m^2$$

$$v_m = \text{sqrt}(k/m) A$$

→ Analogy with gravity/ball

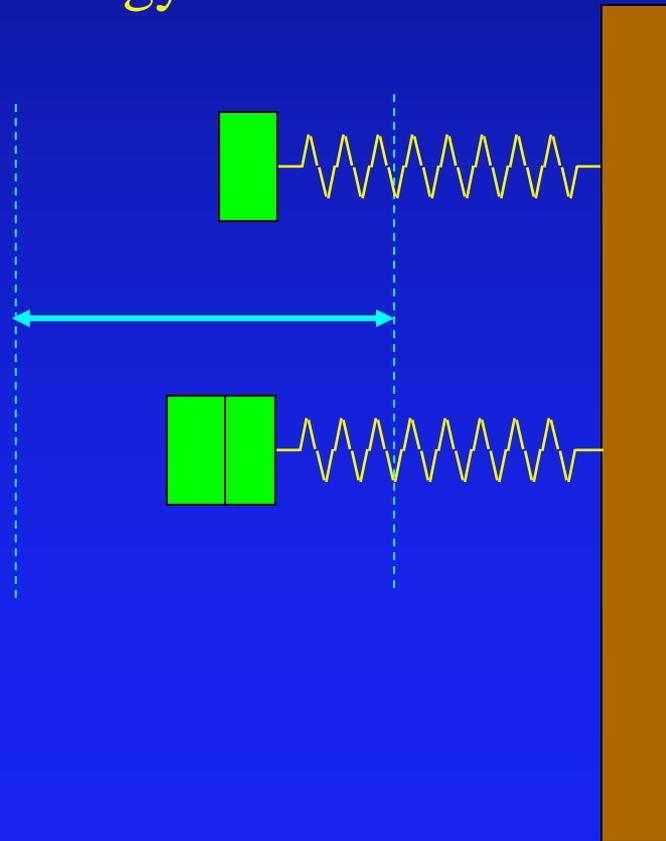


Kinetic Energy ACT

In **Case 1** a mass on a spring oscillates back and forth. In **Case 2**, the mass is doubled but the spring and the amplitude of the oscillation is the same as in Case 1.

In which case is the maximum kinetic energy of the mass the biggest?

- A. Case 1
- B. Case 2
- C. Same



Potential Energy ACT

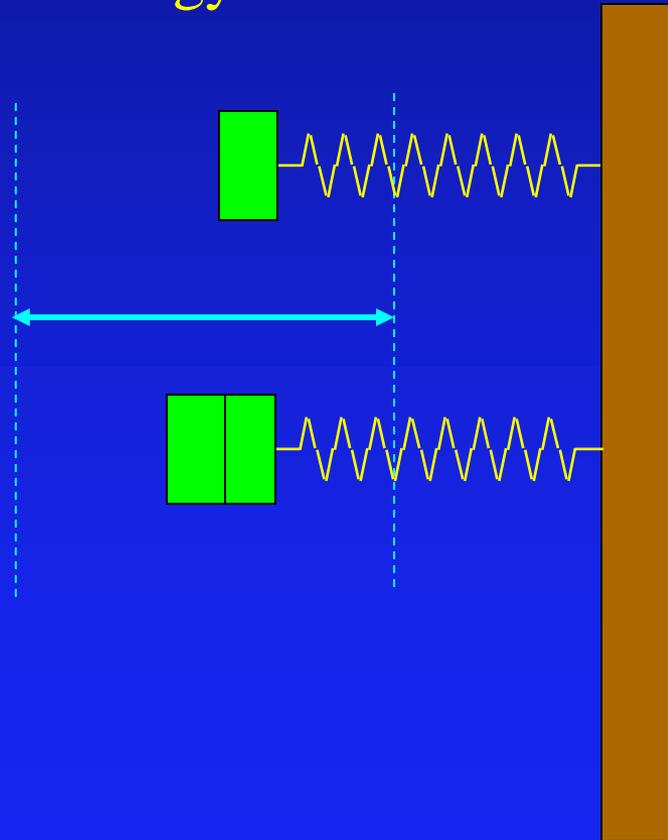
In **Case 1** a mass on a spring oscillates back and forth. In **Case 2**, the mass is doubled but the spring and the amplitude of the oscillation is the same as in Case 1.

In which case is the maximum potential energy of the mass and spring the biggest?

A. Case 1

B. Case 2

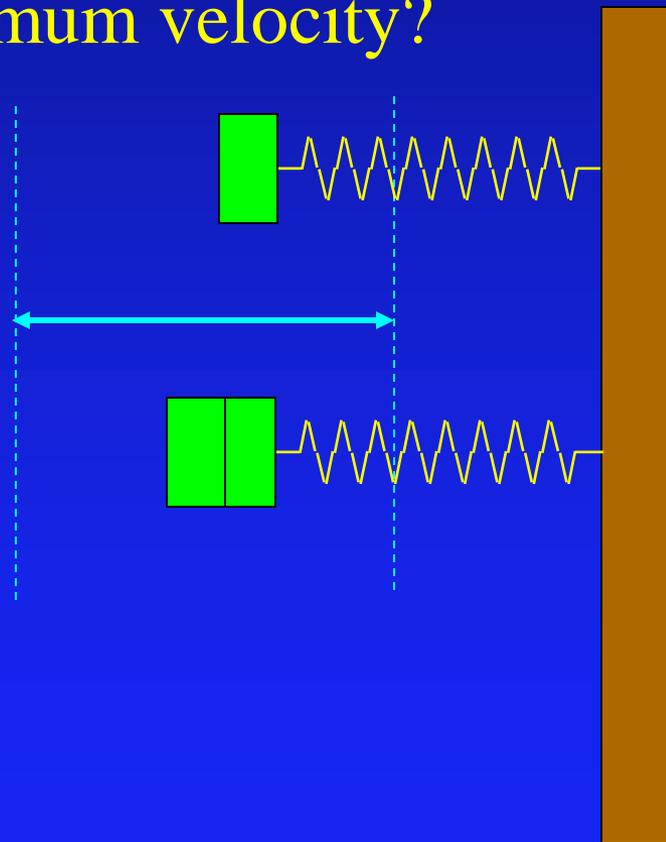
C. Same



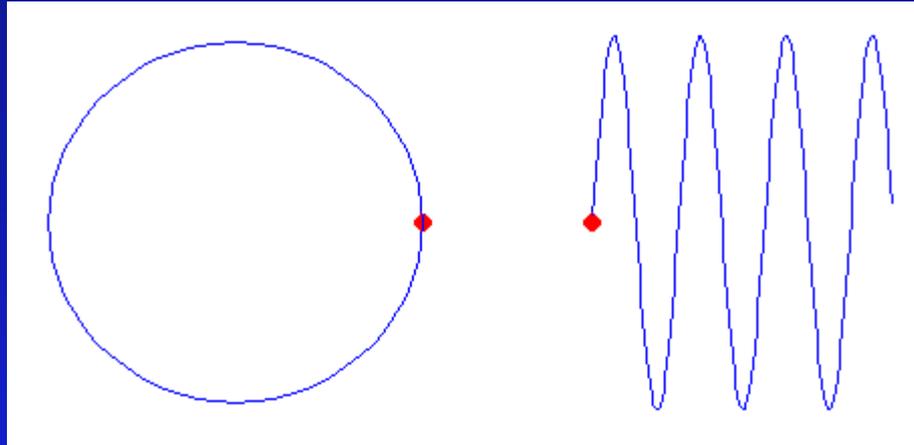
Velocity ACT

In **Case 1** a mass on a spring oscillates back and forth.
In **Case 2**, the mass is doubled but the spring and the amplitude of the oscillation is the same as in Case 1.
Which case has the largest maximum velocity?

1. Case 1
2. Case 2
3. Same



Review: Simple Harmonic Motion



Period = T (seconds per cycle)

Frequency = $f = 1/T$ (cycles per second)

Angular frequency = $\omega = 2\pi f = 2\pi/T$

Period T of a Spring

- Simple Harmonic Oscillator

- $\omega = 2 \pi f = 2 \pi / T$

- $x(t) = [A] \cos(\omega t)$

- $v(t) = -[A\omega] \sin(\omega t)$

- $a(t) = -[A\omega^2] \cos(\omega t)$

Demos:

A, m, k dependence

- Draw FBD write $F=ma$

- $-k x = m a$

- $-k A = m a_{\max}$

- $-k A = m (-A \omega^2)$

- $A\omega^2 = (k/m) A$

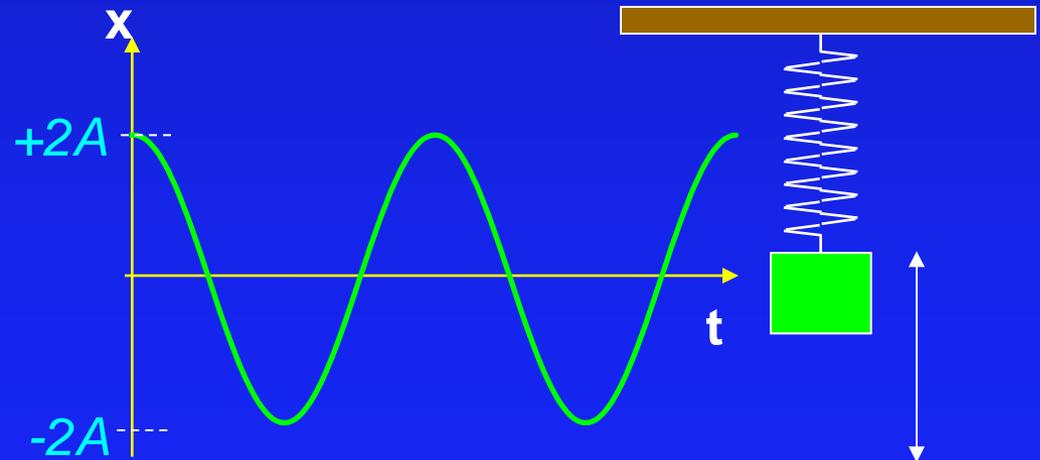
- $\omega = \text{sqrt}(k/m)$

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

Period ACT

If the amplitude of the oscillation (same block and same spring) is doubled, how would the period of the oscillation change? (The period is the time it takes to make one complete oscillation)

- A. The period of the oscillation would double.
- B. The period of the oscillation would be halved
- C. The period of the oscillation would stay the same



Vertical Mass and Spring

- If we include gravity, there are two forces acting on mass. With mass, new equilibrium position has spring stretched d

$$\rightarrow F_{\text{Net}, y} = 0$$

$$kd - mg = 0$$

$$d = mg/k \quad \text{Let this point be } y=0$$

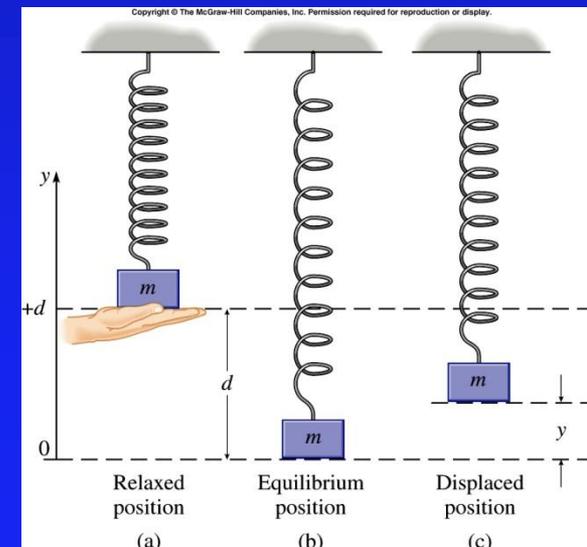
$$\rightarrow F_{\text{Net}} = ma$$

$$k(d-y) - mg = ma$$

$$-k y = ma$$

→ Same as horizontal! SHO

→ New equilibrium position



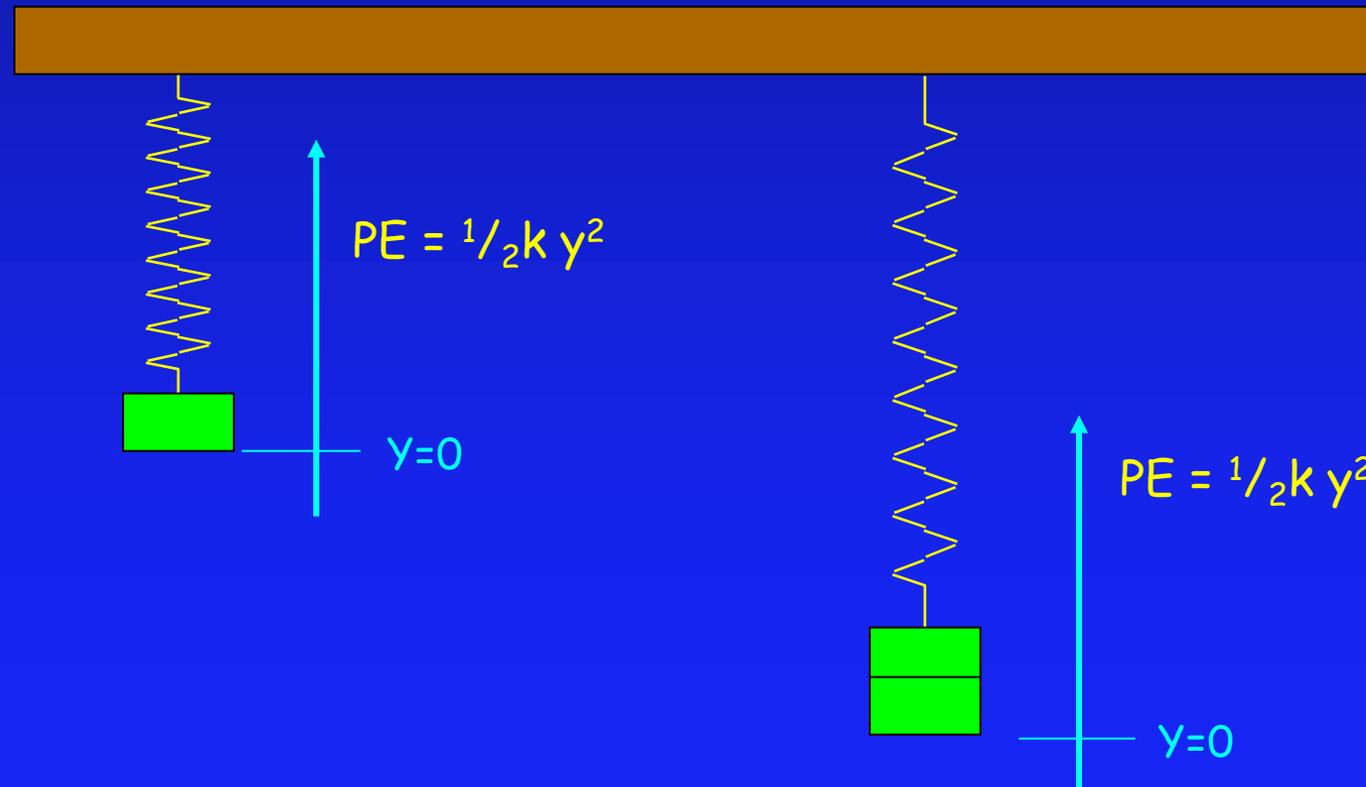
Vertical Spring ACT

If the springs were vertical, and stretched the same distance d from their equilibrium position and then released, which would have the largest maximum kinetic energy?

1) M

2) $2M$

3) Same



Pendulum Motion

- For *small angles*

→ $T = mg$

→ $T_x = -mg (x/L)$ Note: F proportional to x!

→ $F_{\text{Net}, x} = m a_x$

$$-mg (x/L) = m a_x$$

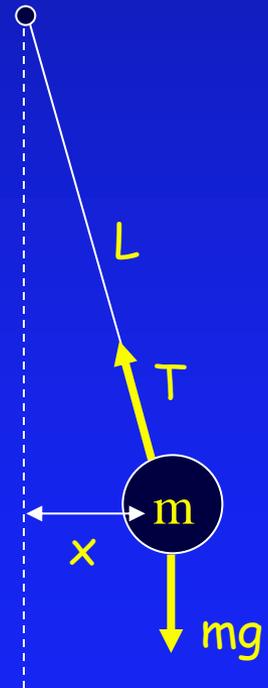
$$a_x = -(g/L) x$$

→ Recall for SHO $a = -\omega^2 x$

$$\omega = \text{sqrt}(g/L)$$

$$T = 2 \pi \text{sqrt}(L/g)$$

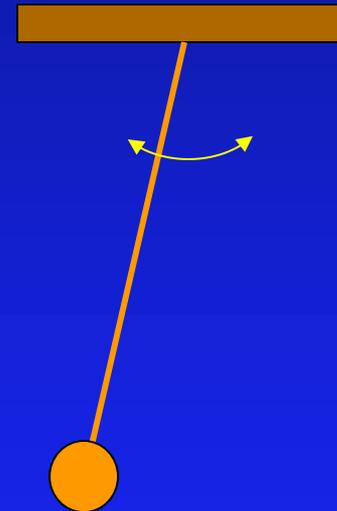
Period does not depend on A, or m!



Preflight 1

Suppose a grandfather clock (a simple pendulum) runs slow. In order to make it run on time you should:

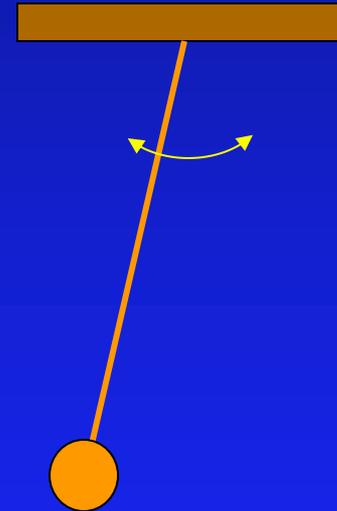
1. Make the pendulum shorter
2. Make the pendulum longer



Elevator ACT

A pendulum is hanging vertically from the ceiling of an elevator. Initially the elevator is at rest and the period of the pendulum is T . Now the elevator accelerates upward. The period of the pendulum will now be

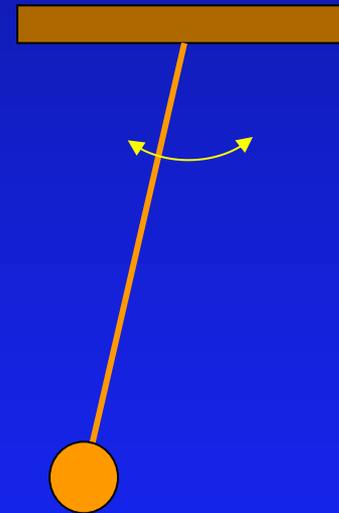
- A. greater than T
- B. equal to T
- C. less than T



ACT

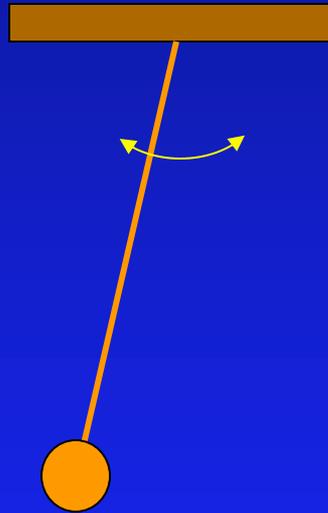
A pendulum is hanging vertically from the ceiling of an elevator. Initially the elevator is at rest and the period of the pendulum is T . Now the elevator accelerates upward. The period of the pendulum will now be. If you are accelerating upward your weight is the same as if g had

1. increased
2. same
3. decreased



Preflight

Imagine you have been kidnapped by space invaders and are being held prisoner in a room with no windows. All you have is a cheap digital wristwatch and a pair of shoes (including shoelaces of known length). Explain how you might figure out whether this room is on the earth or on the moon



Summary

- Simple Harmonic Motion

- Occurs when have linear restoring force $F = -kx$

- $x(t) = [A] \cos(\omega t)$

- $v(t) = -[A\omega] \sin(\omega t)$

- $a(t) = -[A\omega^2] \cos(\omega t)$

- Springs

- $F = -kx$

- $U = \frac{1}{2} k x^2$

- $\omega = \text{sqrt}(k/m)$

- Pendulum (Small oscillations)

- $\omega = \text{sqrt}(L/g)$