

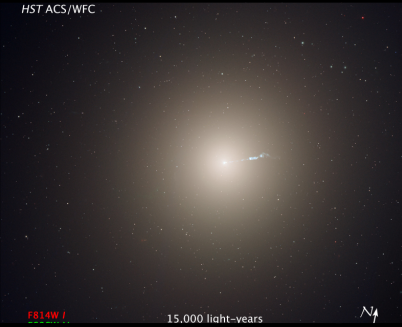


An object hangs motionless from a spring. When the object is pulled down, the sum of the elastic potential energy of the spring and the gravitational potential energy of the object and Earth

- A. increases.
- B. stays the same.
- C. decreases.

	Milky Way	Andromeda	M87
Galaxy			
Mass of SMBH	$4 \times 10^6 M_{\odot}$	$\sim 1.5 \times 10^8 M_{\odot}$	$6.4 \times 10^9 M_{\odot}$
Schwarzschild radius	$1 \times 10^{10} \text{ m}$	$\sim 4.4 \times 10^{11} \text{ m}$	$1.9 \times 10^{13} \text{ m}$
SMBH density	$1 \times 10^6 \text{ kg/m}^3$	$\sim 800 \text{ kg/m}^3$	$0.45 \text{ kg/m}^3$

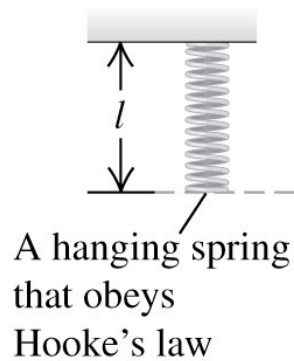
# Ch 14.4-6

# Pendula

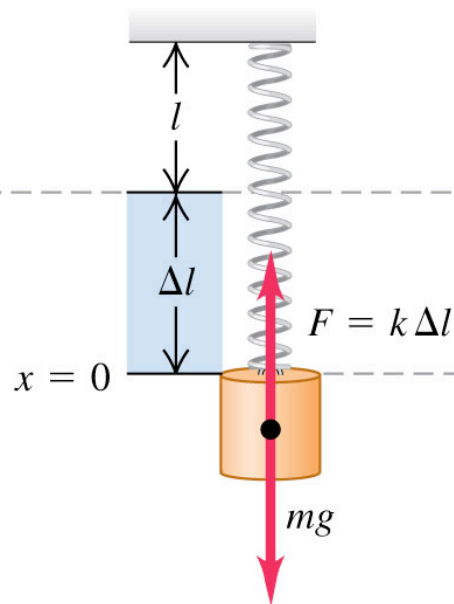
PHYS 1210 -- Prof. Jang-Condell

# Spring + Gravity

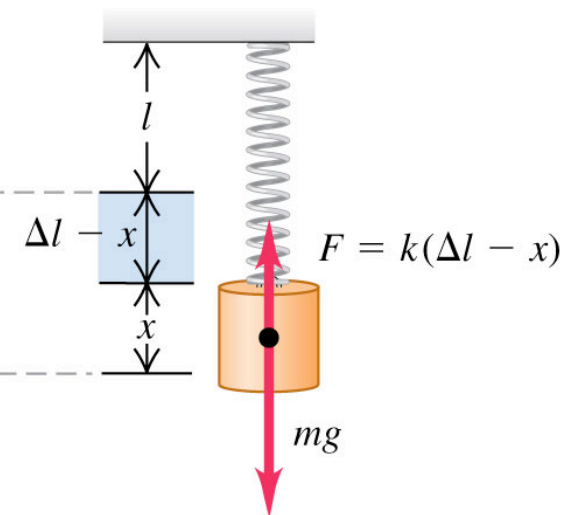
(a)



(b) A body is suspended from the spring. It is in equilibrium when the upward force exerted by the stretched spring equals the body's weight.

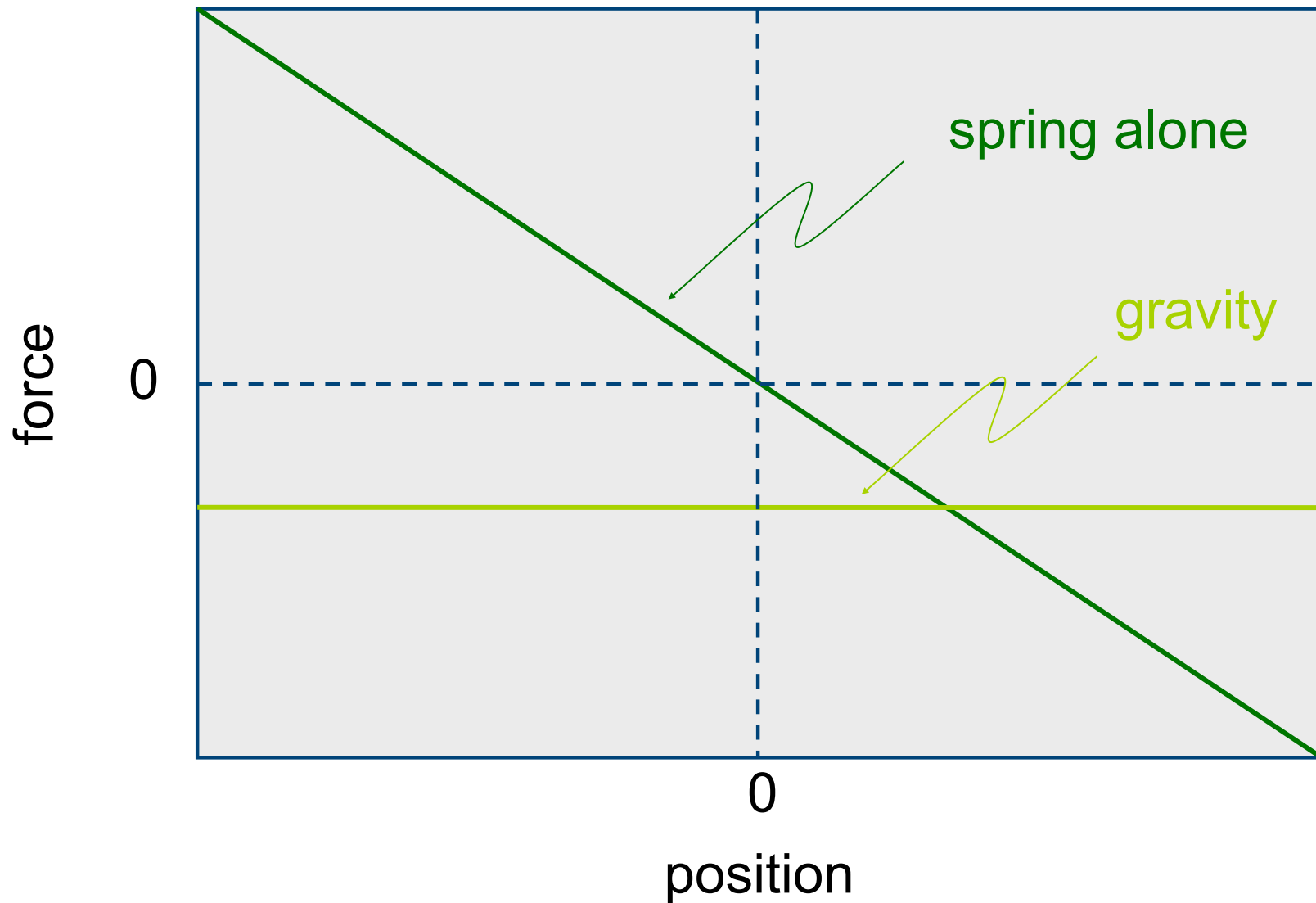


(c) If the body is displaced from equilibrium, the net force on the body is proportional to its displacement. The oscillations are SHM.

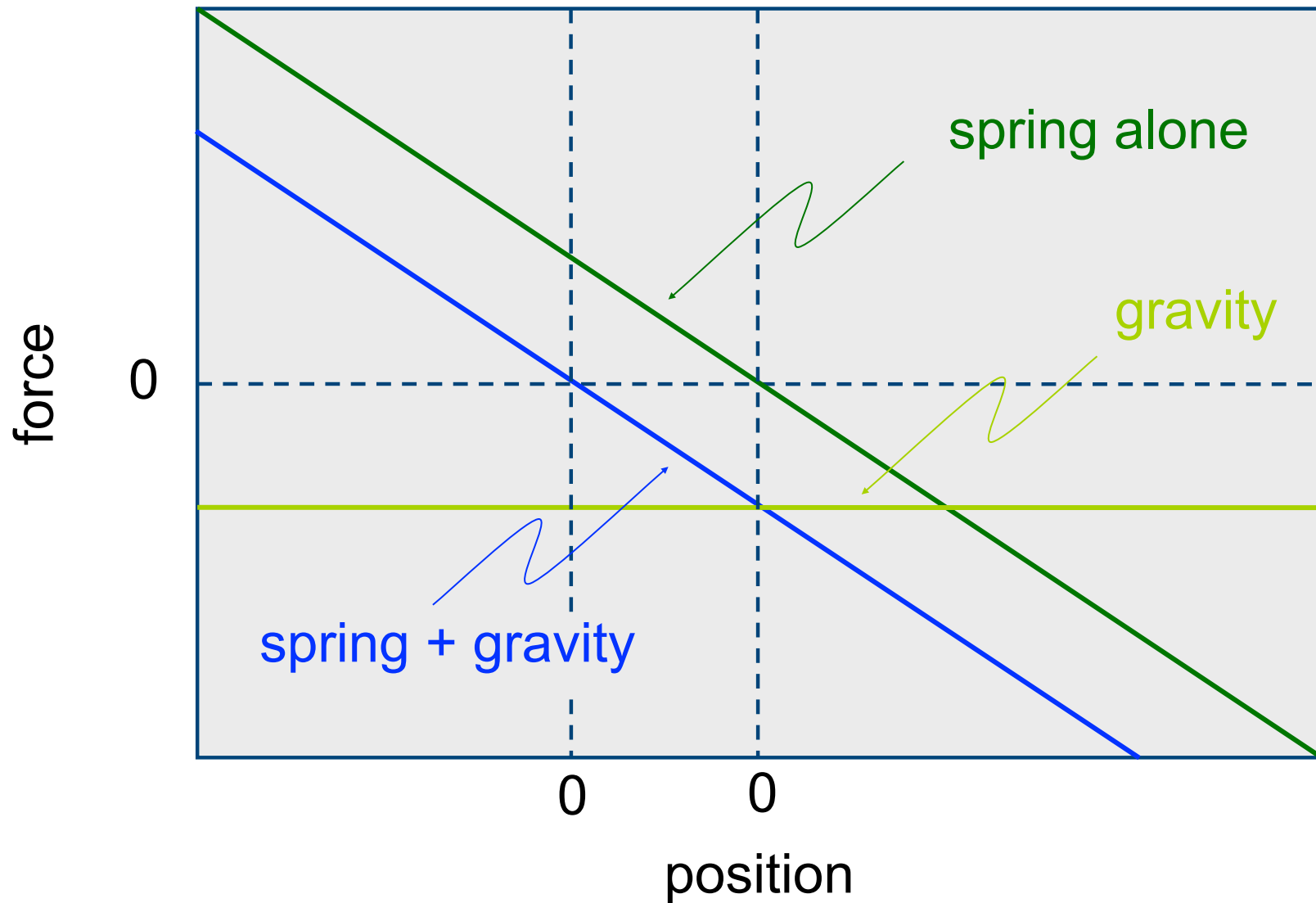


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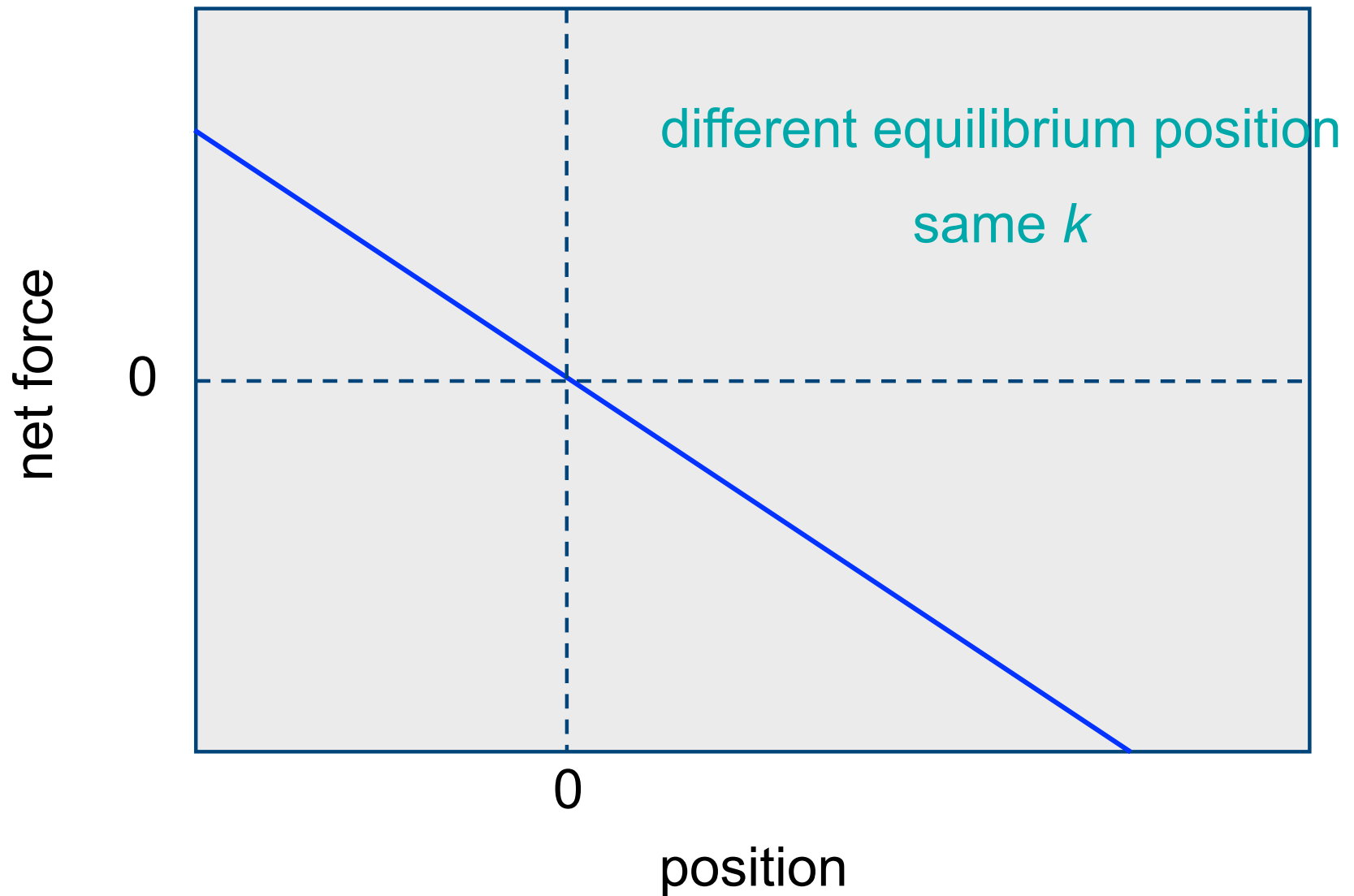
# Spring + Gravity



# Spring + Gravity



# Spring + Gravity



# Simple Harmonic Motion

$$x = A \cos(\omega t + \phi) \quad (\text{displacement in SHM})$$

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

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

$$T = \frac{1}{f} = \frac{2\pi}{\omega} = 2\pi \sqrt{\frac{m}{k}}$$

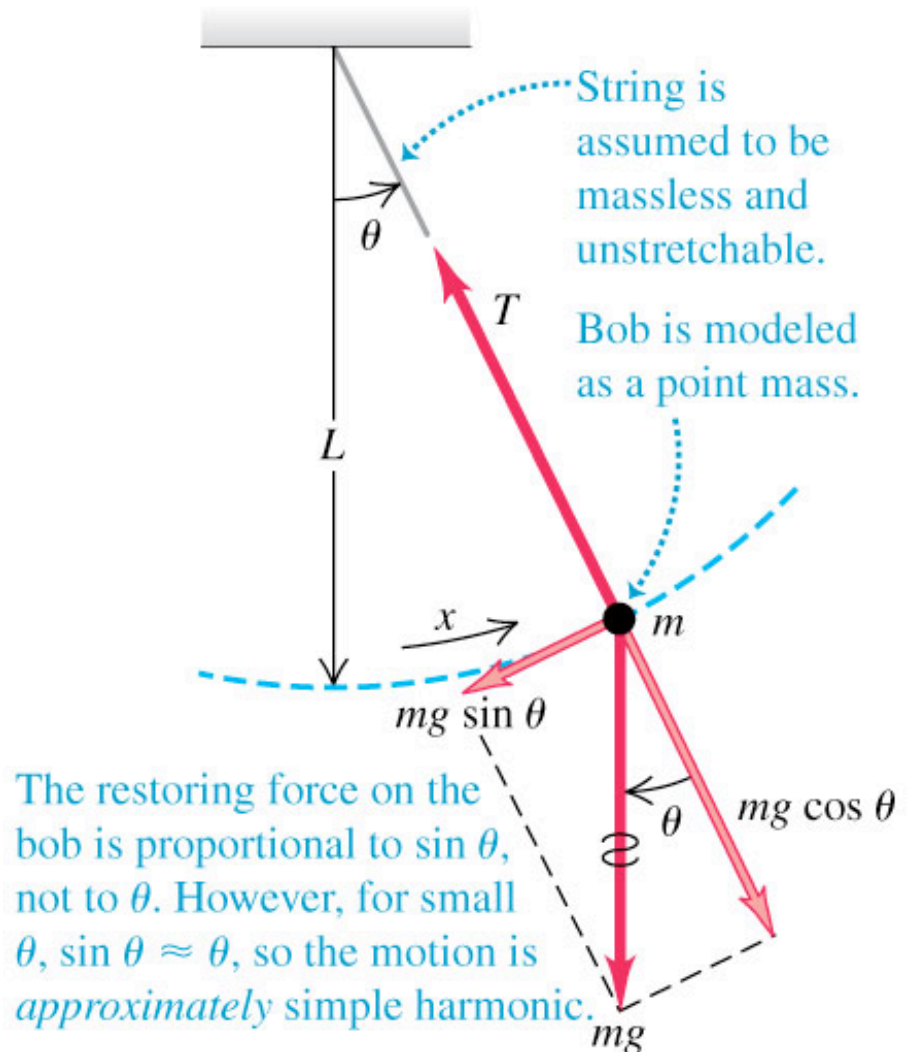
$$E = \frac{1}{2}mv_x^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 = \text{constant}$$



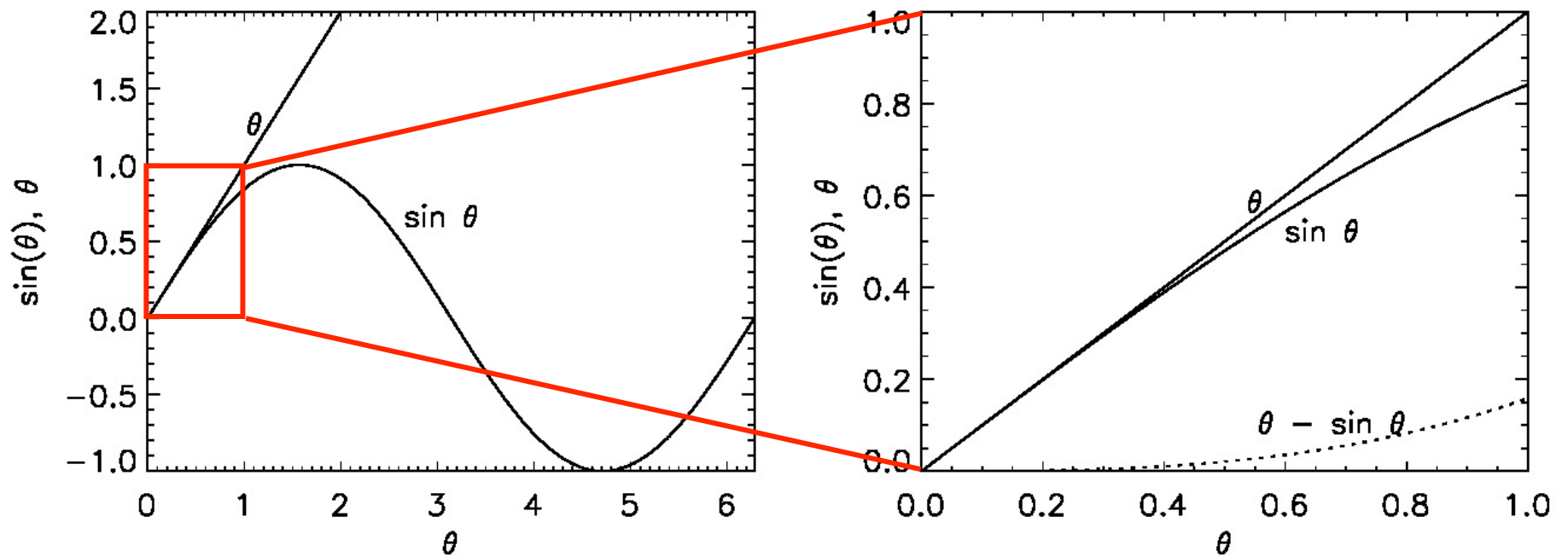
# The simple pendulum

- A *simple pendulum* consists of a point mass (the bob) suspended by a massless, unstretchable string.
- If the pendulum swings with a small amplitude  $\theta$  with the vertical, its motion is simple harmonic. (See Figure 14.21 at the right.)

(b) An idealized simple pendulum



# Small angle approximation



$$\sin\theta \sim \theta \text{ for } \theta \ll 1$$

# Simple Pendulum

$$x = A \cos(\omega t + \phi) \quad (\text{displacement in SHM})$$

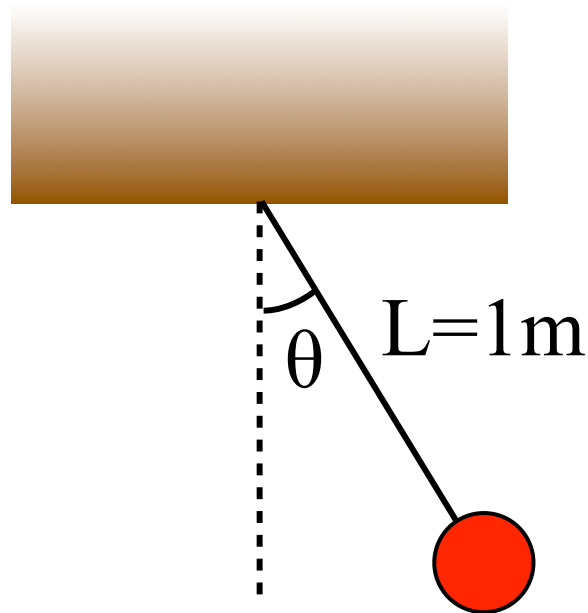
$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{mg/L}{m}} = \sqrt{\frac{g}{L}} \quad (\text{simple pendulum, small amplitude}) \quad (14.32)$$

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi} \sqrt{\frac{g}{L}} \quad (\text{simple pendulum, small amplitude}) \quad (14.33)$$

$$T = \frac{2\pi}{\omega} = \frac{1}{f} = 2\pi \sqrt{\frac{L}{g}} \quad (\text{simple pendulum, small amplitude}) \quad (14.34)$$

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Calculate the period of a simple pendulum with length 1.00 m, and mass  $M$



The period of a 1-m long simple pendulum is almost exactly 2s. For a pendulum of period 1s, how long must it be?

F. 25 cm

G. 50 cm

H. 1 m

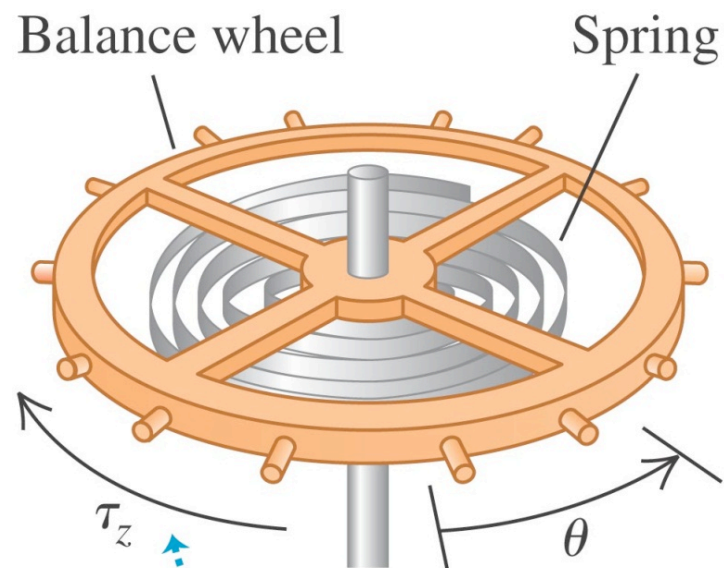
I. 2 m

J. 4 m

Text your answer to 22333.

# Angular SHM

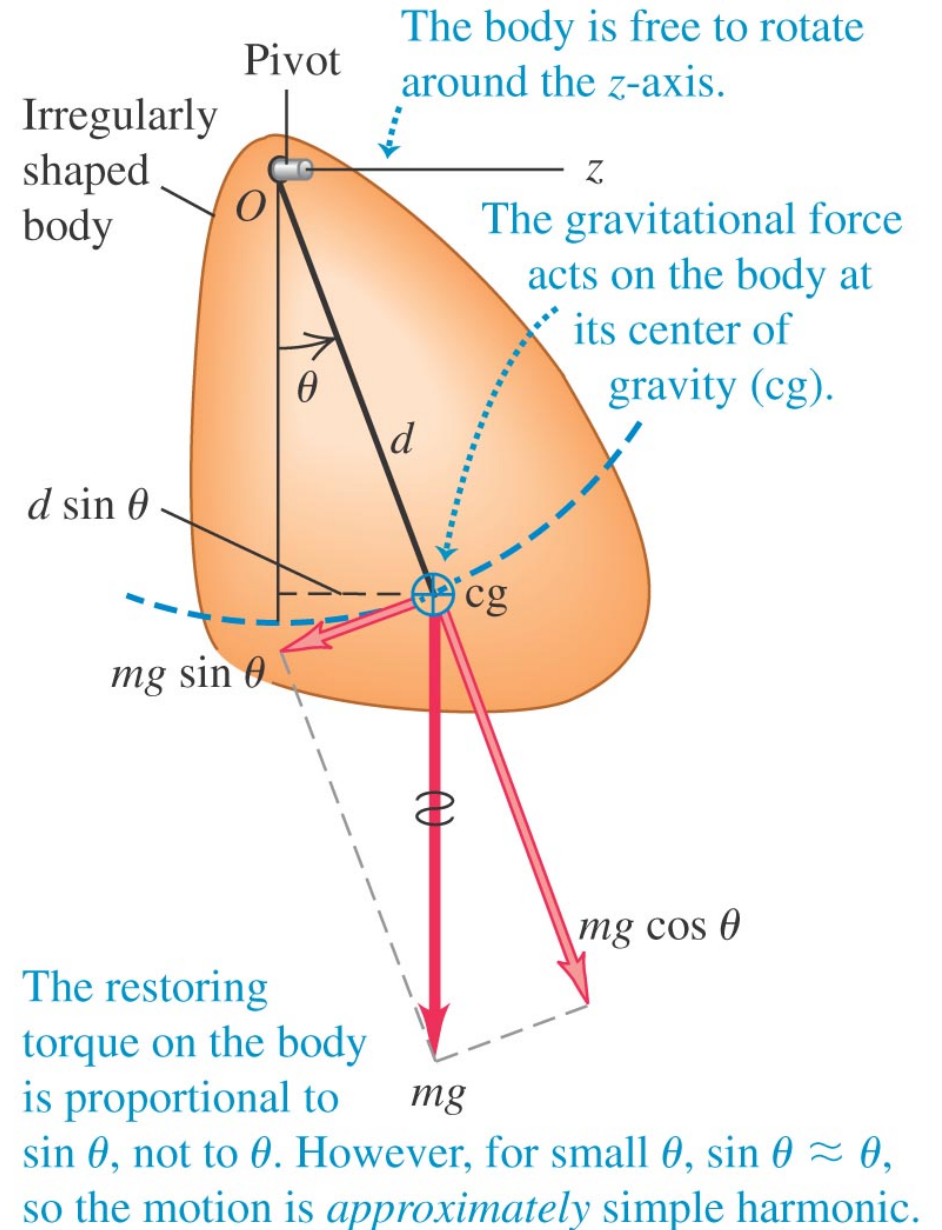
- A coil spring (see Figure 14.19 below) exerts a restoring torque  $\tau_z = -\kappa\theta$ , where  $\kappa$  is called the *torsion constant* of the spring.
- The result is *angular* simple harmonic motion.



The spring torque  $\tau_z$  opposes the angular displacement  $\theta$ .

# The physical pendulum

- A *physical pendulum* is any real pendulum that uses an extended body instead of a point-mass bob.
- For small amplitudes, its motion is simple harmonic. (See Figure 14.23 at the right.)



# Physical Pendulum

$$\omega = \sqrt{\frac{mgd}{I}} \quad (\text{physical pendulum, small amplitude}) \quad (14.38)$$

$$T = 2\pi \sqrt{\frac{I}{mgd}} \quad (\text{physical pendulum, small amplitude}) \quad (14.39)$$

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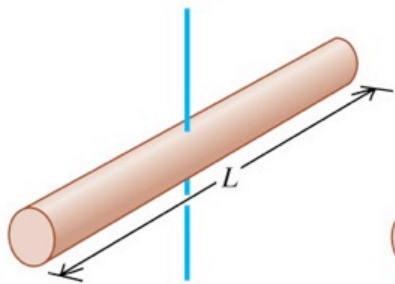
- $d$  = distance between **pivot** and **CoM**
- $I$  = moment of inertia, rotating about **pivot**



**Table 9.2 Moments of Inertia of Various Bodies**

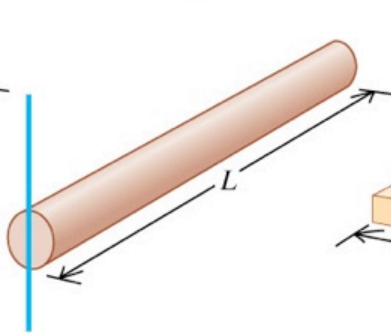
(a) Slender rod, axis through center

$$I = \frac{1}{12} ML^2$$



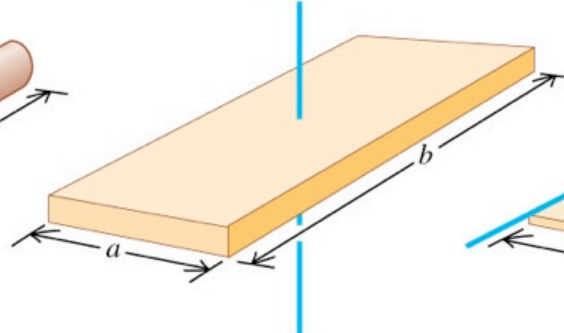
(b) Slender rod, axis through one end

$$I = \frac{1}{3} ML^2$$



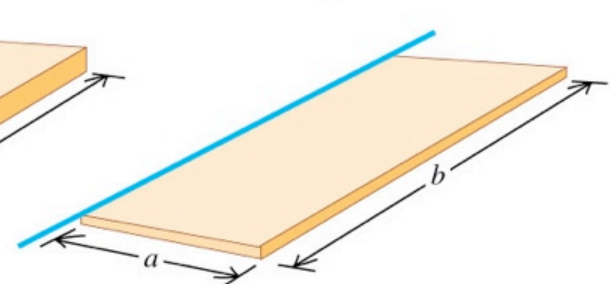
(c) Rectangular plate, axis through center

$$I = \frac{1}{12} M(a^2 + b^2)$$



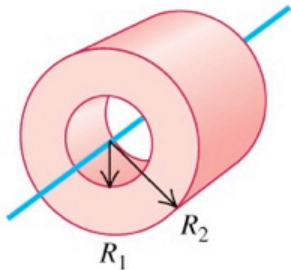
(d) Thin rectangular plate, axis along edge

$$I = \frac{1}{3} Ma^2$$



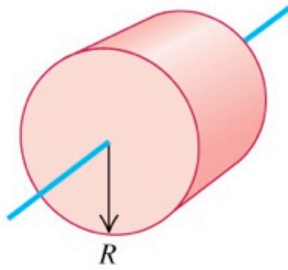
(e) Hollow cylinder

$$I = \frac{1}{2} M(R_1^2 + R_2^2)$$



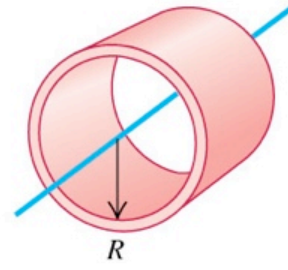
(f) Solid cylinder

$$I = \frac{1}{2} MR^2$$



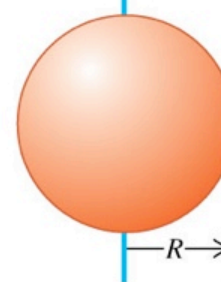
(g) Thin-walled hollow cylinder

$$I = MR^2$$



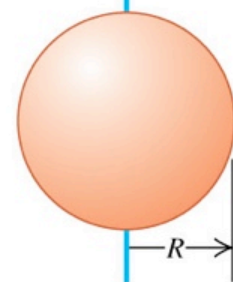
(h) Solid sphere

$$I = \frac{2}{5} MR^2$$



(i) Thin-walled hollow sphere

$$I = \frac{2}{3} MR^2$$



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How does the period of a solid bar compare to a simple pendulum having the same distance to the center of mass?

K. Shorter period

L. Longer period

M. The same period

N. Not enough information

Text your answer to 22333

