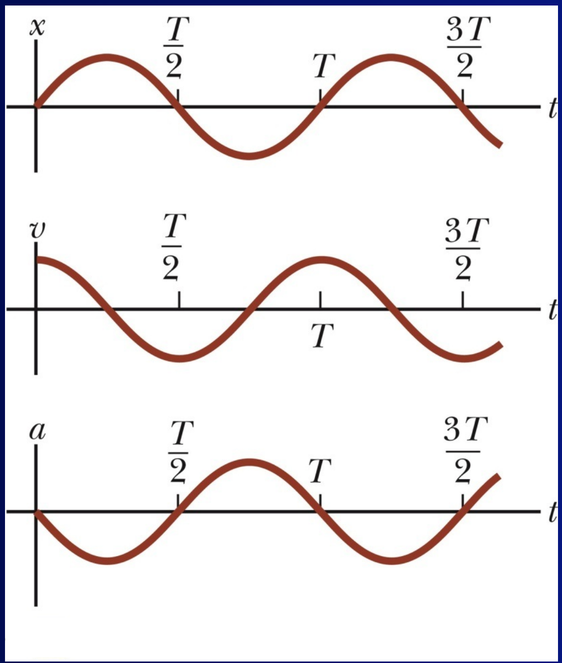
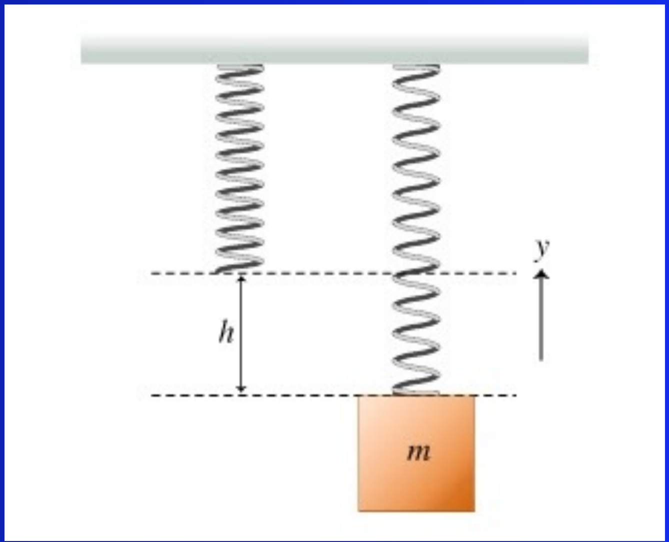
Physics 1C: Simple Harmonic Motion

Friday, 3 April 2015





Important Info

- course website: http://ted.ucsd.edu
- backup course website: http://cass.ucsd.edu/~rskibba/work/Teaching.html

- http://www.webassign.net

  self-enroll with our 1C class key: `ucsd 2397 3544`

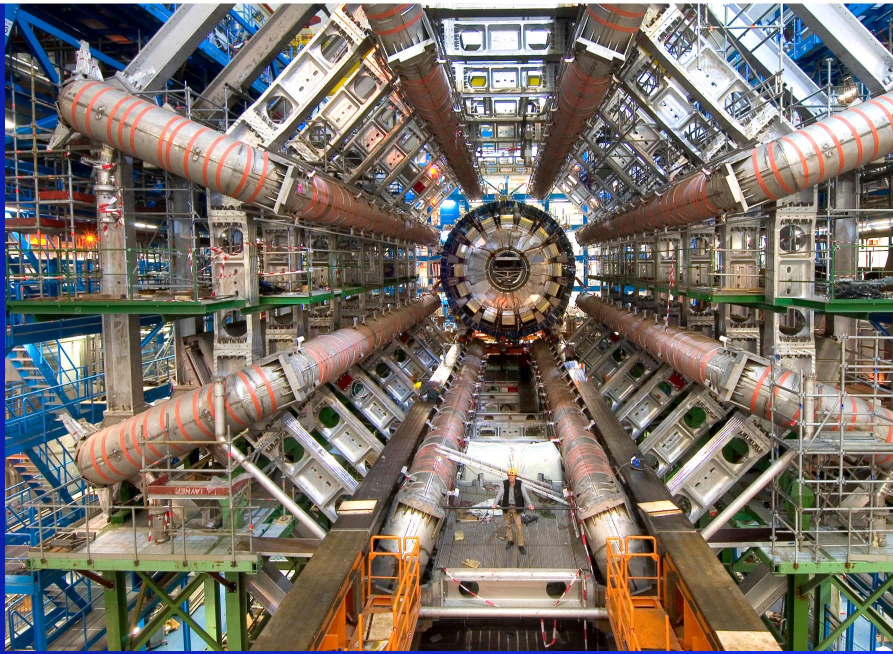
"Chapter 12 Homework Assignment" and "Chapter 12 Suggested Problems" are available on WebAssign. They're not due for grades but you should work through them.

Chapter 12 Reading Quiz will be up on WebAssign; it's now at least on the Ted site (along with syllabus and first two lectures)

Reminders

- make sure to register your clicker! next week, your class participation will count.
- next week's homework assignment will need to be completed on WebAssign by next Friday at 1pm
- the first test will be next Friday at 1pm
- if after reading the book and working on problems you have difficulty with anything, take advantage of office hours and the TA's problem sessions (Thursdays)

Physics News



- particle physics: Large Hadron Collider particle accelerator (discoverer of Higgs boson) restarts after two-year hiatus

- optics: 2015 is the International Year of Light; Physical Review journals highlight important breakthroughs in optics

- relativity: scientists celebrate Einstein's publication of General Relativity theory 100 years ago

- astrophysics: Dark Energy Survey scientists discover nine new dwarf galaxies orbiting our Milky Way

Simple Harmonic Motion (SHM)

position $$x = A\cos(\omega t + \phi_0)$$

velocity $$\frac{dx}{dt} = -A\omega\sin(\omega t + \phi_0)$$

acceleration $$\frac{d^2x}{dt^2} = -A\omega^2\cos(\omega t + \phi_0)$$

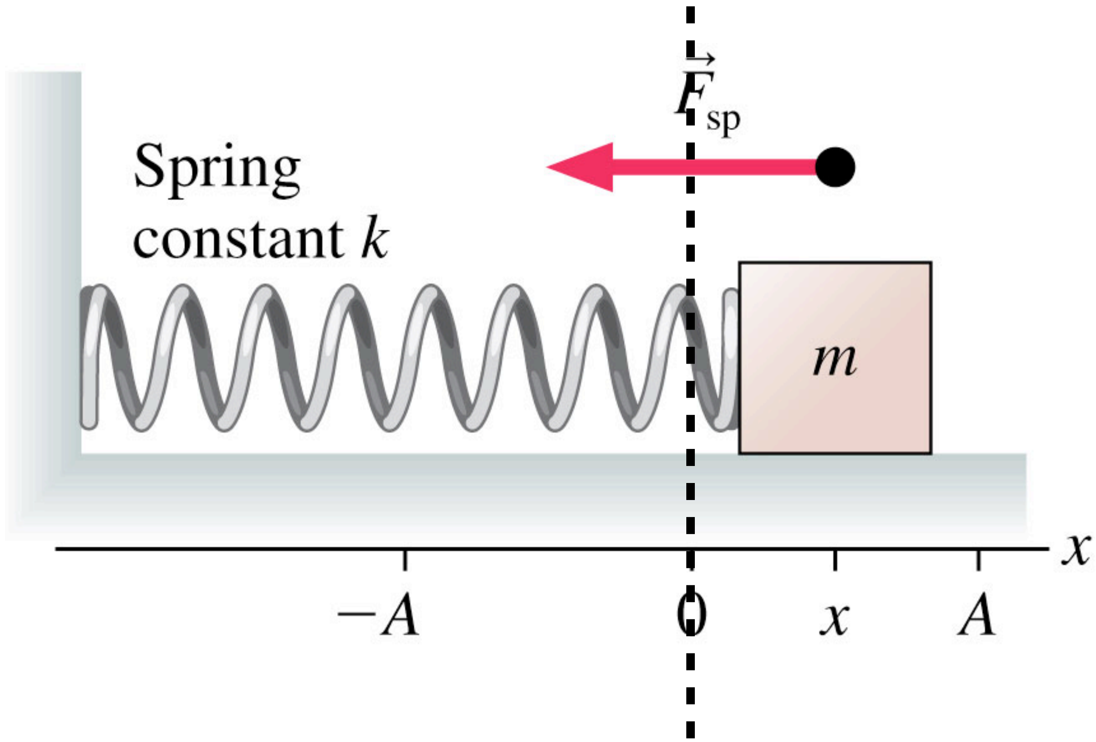
$$\frac{d^2x}{dt^2} = -\omega^2 x$$

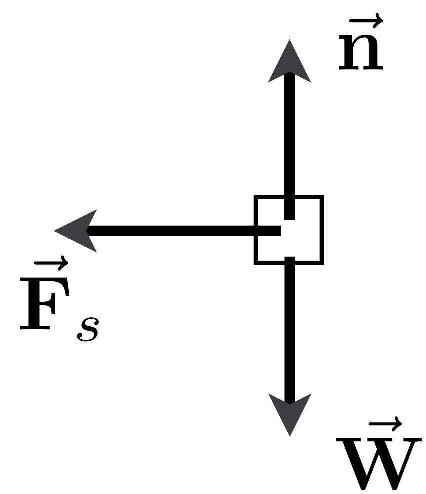
$$F_{\text{net}} = m\frac{d^2x}{dt^2} = -m\omega^2 x$$

"linear restoring force"

Simple Harmonic Motion

$$F_{\text{net}} = -m\omega^2 x$$





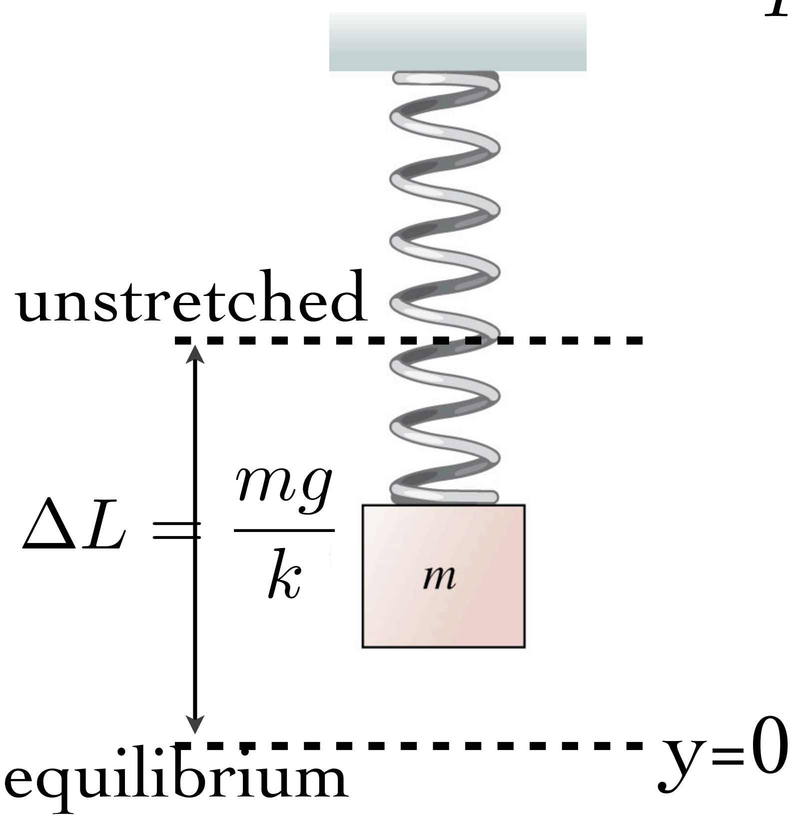
$$F_{\text{net}} = -kx$$

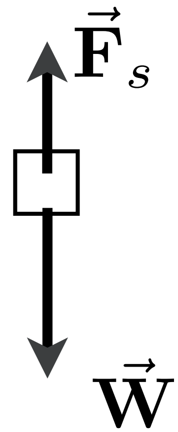
equilibrium

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

Simple Harmonic Motion

$$F_{\text{net}} = -m\omega^2 x$$





$$F_{\text{net}} = -mg + k(\Delta L - y)$$

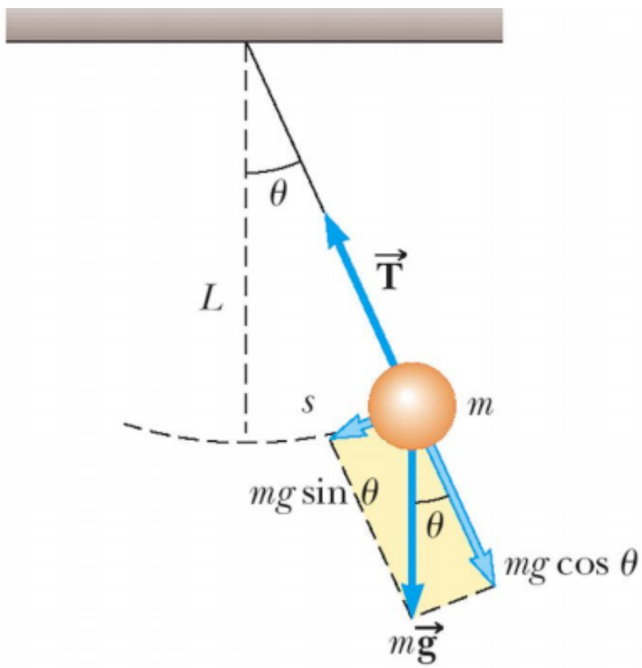
$$F_{\text{net}} = -ky + (k\Delta L - mg)$$

$$F_{\text{net}} = -ky$$

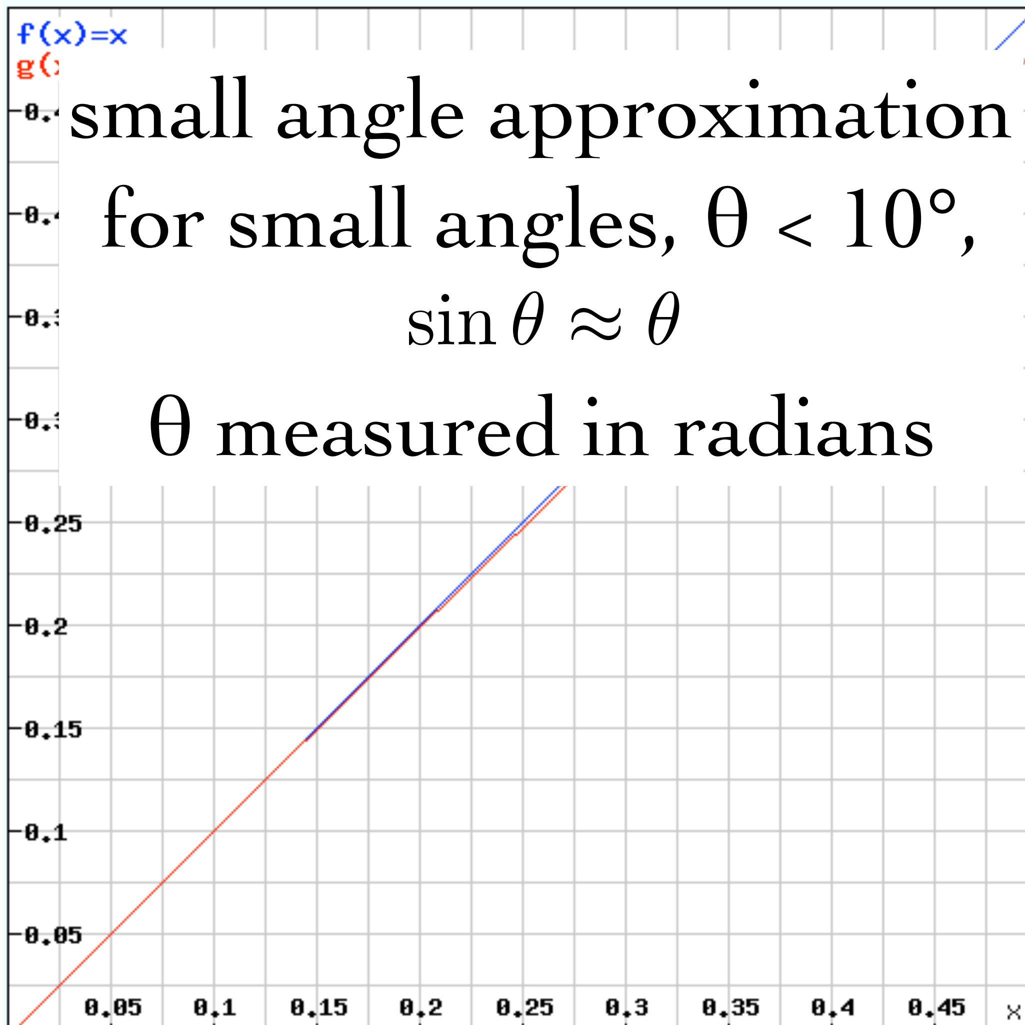
$$\omega = \sqrt{\frac{k}{m}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

Simple Harmonic Motion: Pendulum

$$F_{\text{net}} = -m\omega^2 x$$



$$F_{\text{net},t} = -mg\sin\theta$$



small angle approximation

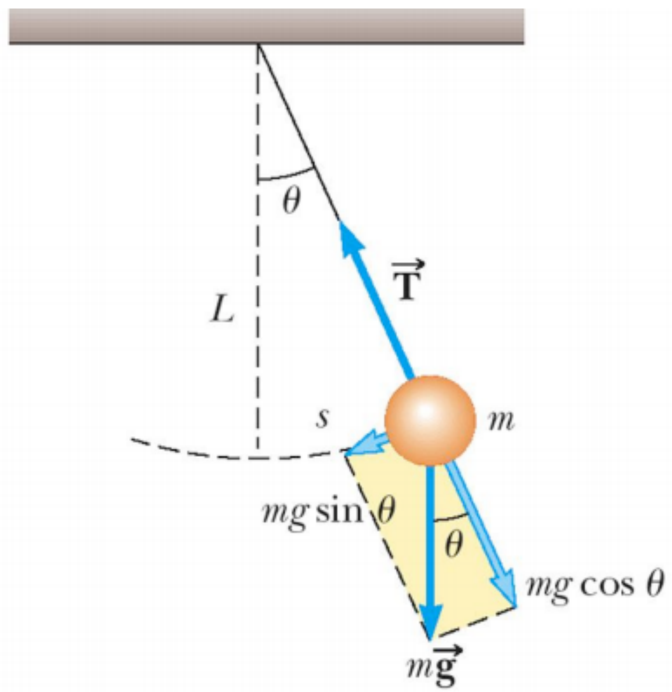
for small angles, θ < 10°,

$\sin\theta \approx \theta$

θ measured in radians

Simple Harmonic Motion: Pendulum

$$F_{\text{net}} = -m\omega^2 x$$

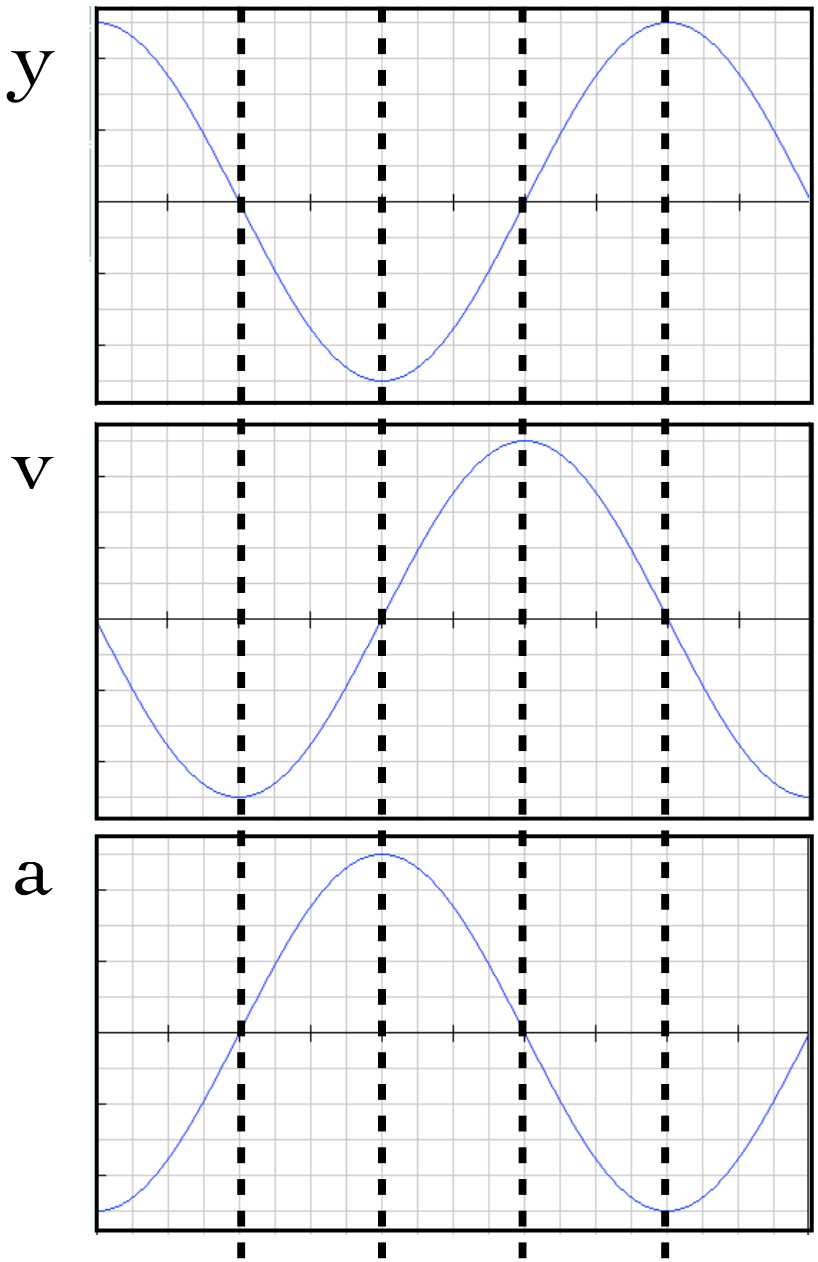


$$F_{\text{net},t} = -mg\sin\theta$$

$$F_{\text{net},t} \approx -m\frac{g}{L}s$$

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

Simple Harmonic Motion: Pendulum



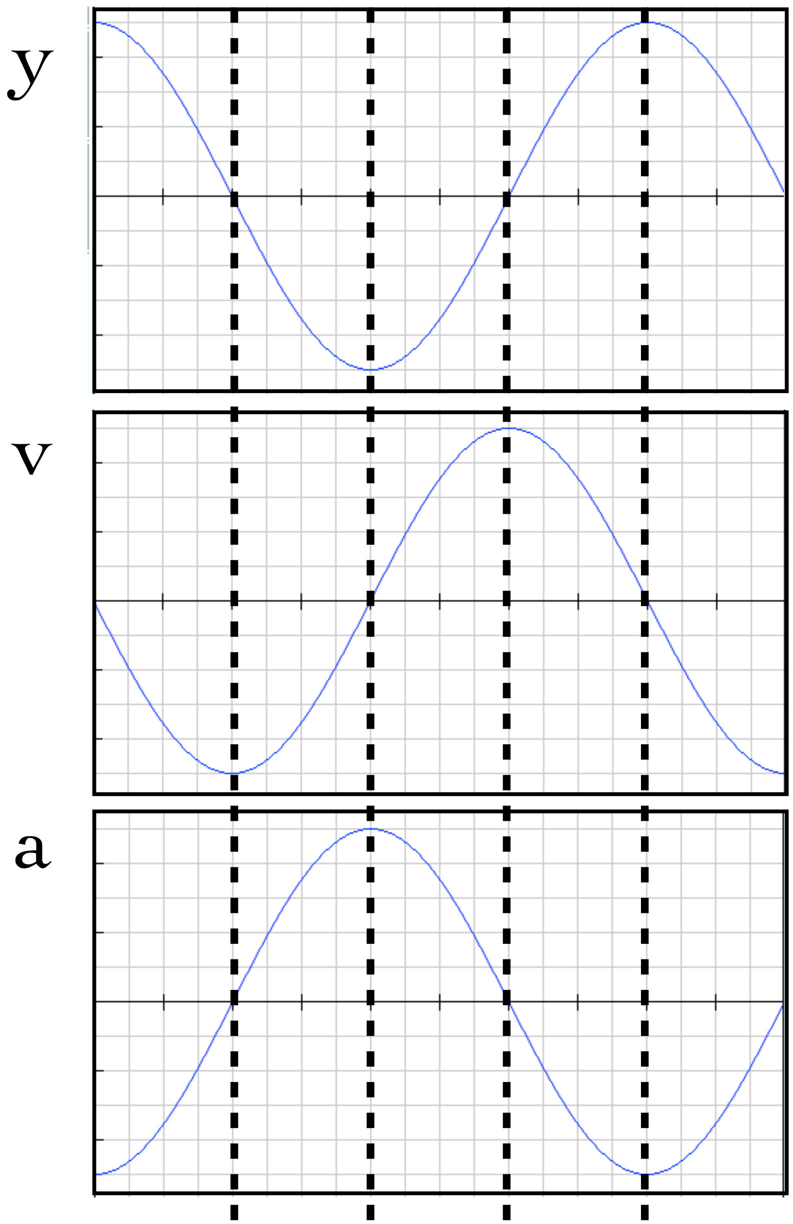
$$y = A\cos(\omega t + \phi_0)$$

$$\text{phase} = \omega t + \phi_0$$

What is the phase when the position of the mass is at its minimum value?

A. 0
B. π/2
C. π
D. 3π/2
E. more than one of these

Simple Harmonic Motion: Pendulum



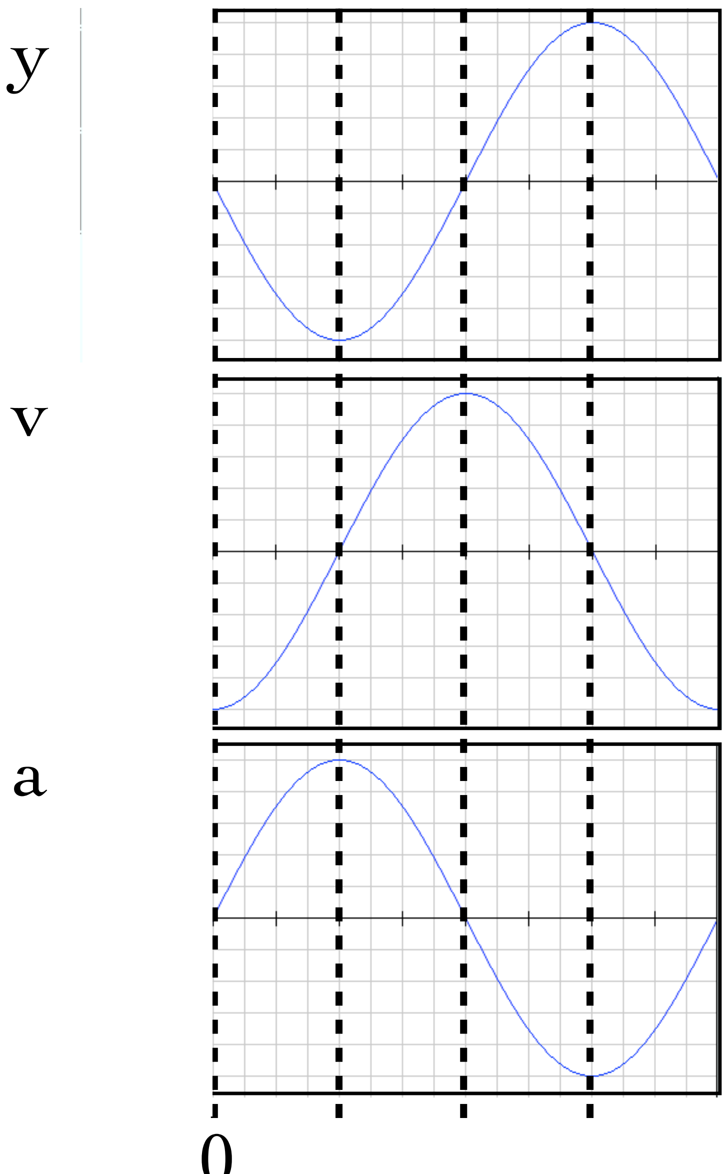
$$y = A\cos(\omega t + \phi_0)$$

$$\text{phase} = \omega t + \phi_0$$

What is the phase when the position of the mass is at its equilibrium (y=0) value?

A. 0
B. π/2
C. π
D. 3π/2
E. more than one of these

Simple Harmonic Motion: Pendulum



$$y = A\cos(\omega t + \phi_0)$$

$$\text{phase} = \omega t + \phi_0$$

$$\text{phase constant} = \phi_0$$

What does the phase constant mean?

The phase constant tells us
the initial phase:
where to start the graph at t = 0.

for example, when $\phi_0 = \dfrac{\pi}{2}$

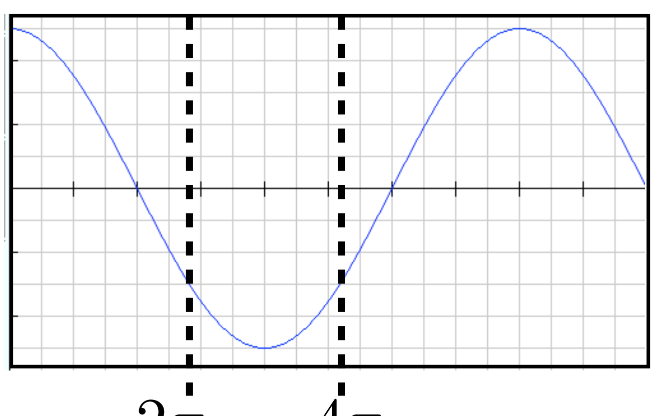
SHM: spring example

A mass on a spring oscillates with period 0.80 s and amplitude 10 cm. At t = 0 s, it is 5.0 cm to the left of equilibrium and moving to the left. What are the position and velocity of the mass at time t = 2.0 s?

$$x = A\cos(\omega t + \phi_0) \qquad t = 0 \qquad x = -5.0\ \text{cm}$$

$$A = 10\ \text{cm} \qquad \omega = \frac{2\pi}{T} = 7.854\ \text{rad/s}$$

$$-5.0\ \text{cm} = (10\ \text{cm})\cos\phi_0$$



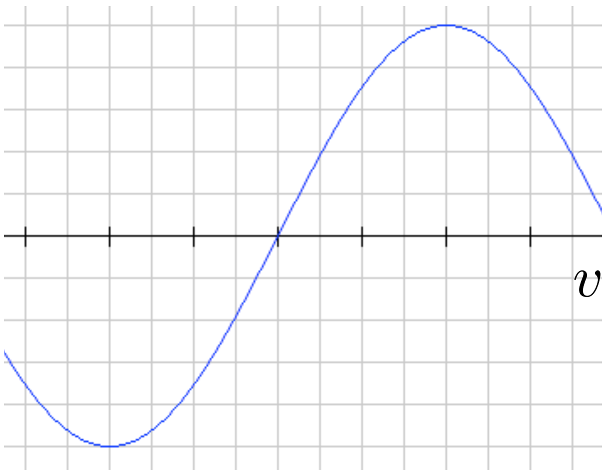
$$\frac{2\pi}{3}, \quad \frac{4\pi}{3}$$

$$\phi_0 = \frac{2\pi}{3}, \frac{4\pi}{3}$$

$$x = (10\ \text{cm})\cos\left((7.854\ \text{rad/s})t + \frac{2\pi}{3}\right)$$

SHM: spring example

A mass on a spring oscillates with period 0.80 s and amplitude 10 cm. At t = 0 s, it is 5.0 cm to the left of equilibrium and moving to the left. What are the position and velocity of the mass at time t = 2.0 s?



$$x(t) = (10\ \mathrm{cm})\cos\left((7.854\ \mathrm{rad/s})t + \frac{2\pi}{3}\right)$$

$$v(t) = -(78.54\ \mathrm{cm/s})\sin\left((7.854\ \mathrm{rad/s})t + \frac{2\pi}{3}\right)$$

$$x(2\ \mathrm{s}) = 5.0\ \mathrm{cm}$$

$$v(2\ \mathrm{s}) = 68\ \mathrm{cm/s}$$

Conservation of Energy

total energy $E = K + U = (1/2)kA^2 =$ constant!

- Assume a spring-mass system is moving on a frictionless surface
- This is an isolated system, so the total energy is constant
  - The kinetic energy is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2 A^2 \sin^2(\omega t + \phi)$$

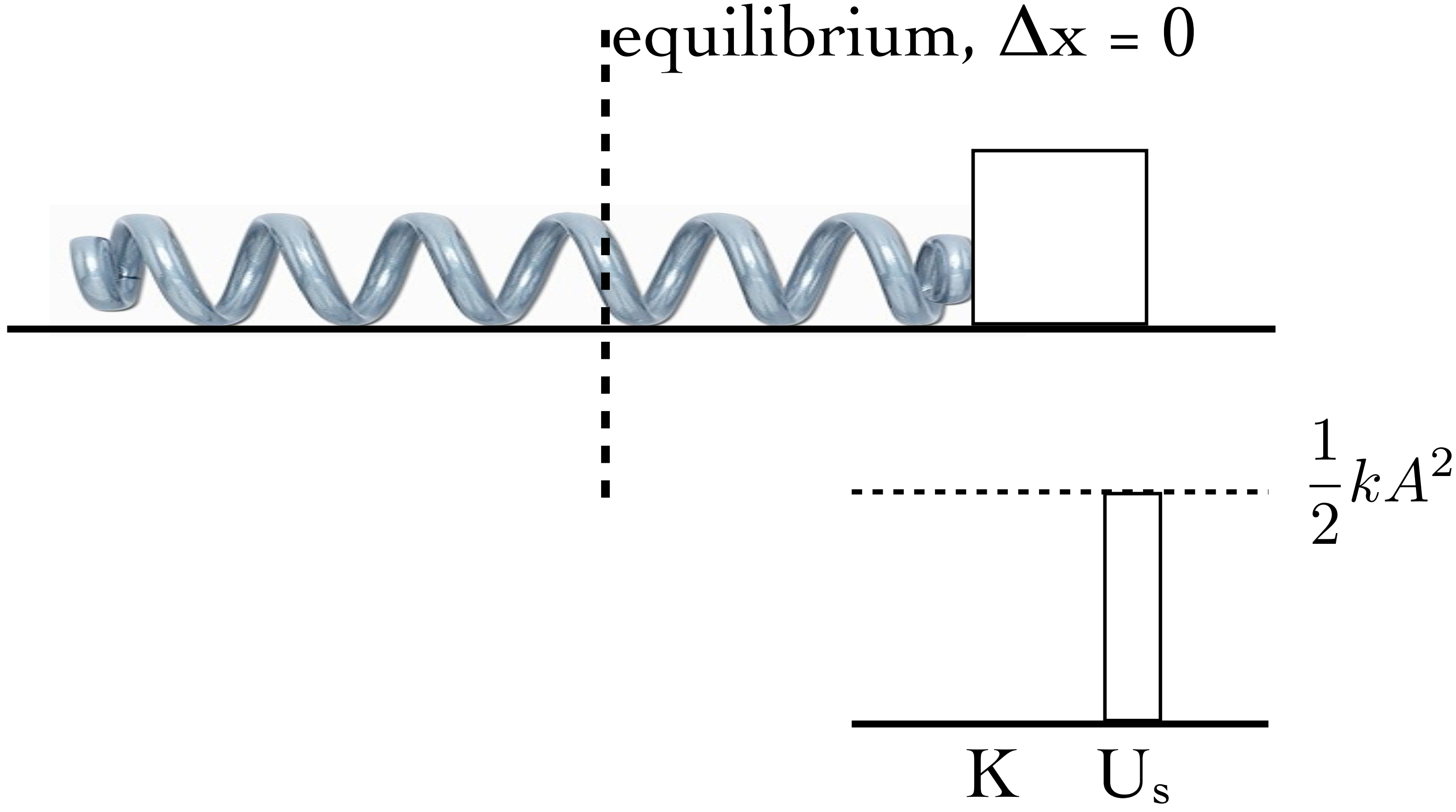
  - The elastic potential energy is

$$U = \frac{1}{2}kx^2 = \frac{1}{2}kA^2 \cos^2(\omega t + \phi)$$

Conservation of Energy

block released from rest

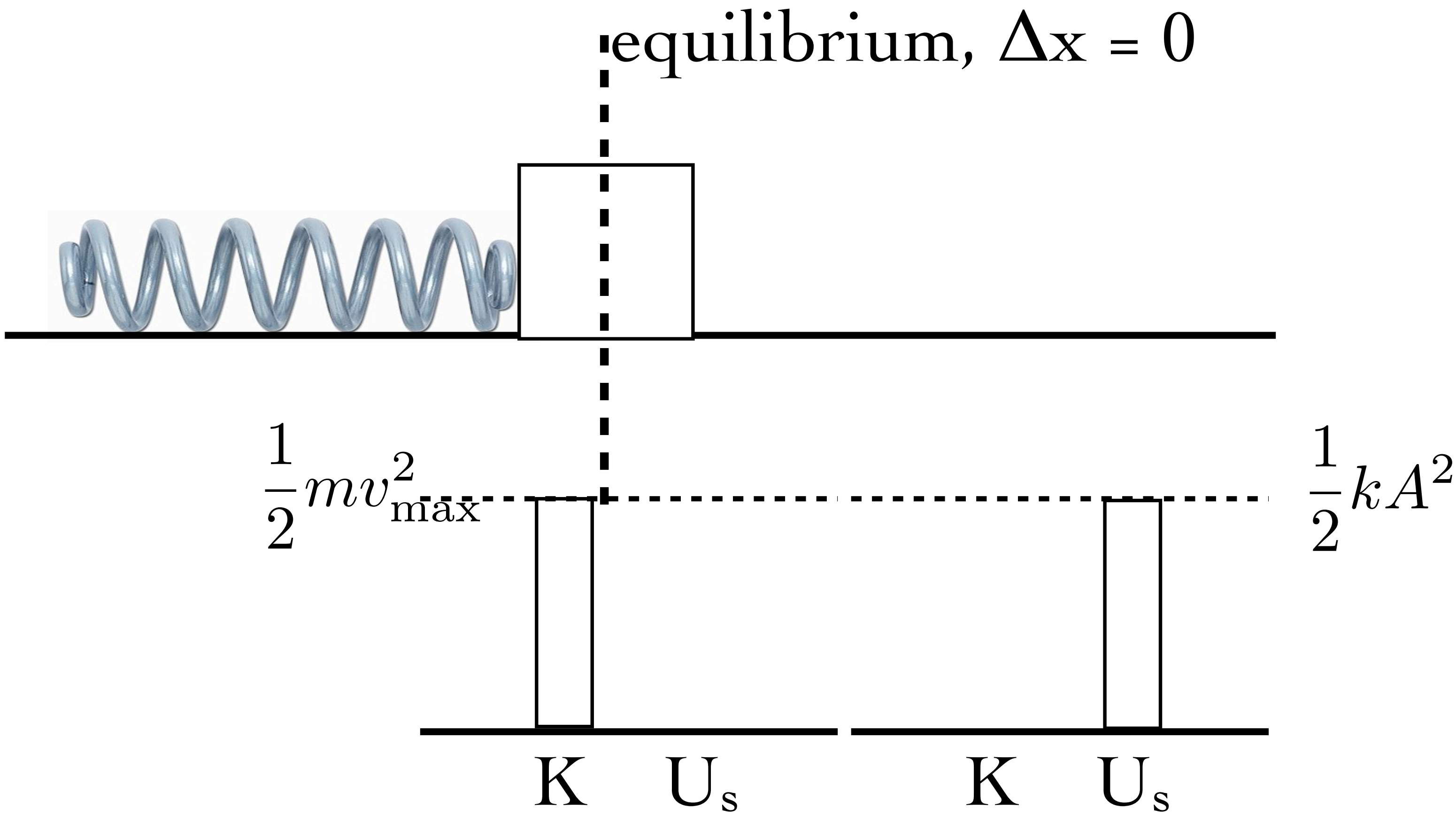
A = Amplitude



Conservation of Energy

block released from rest

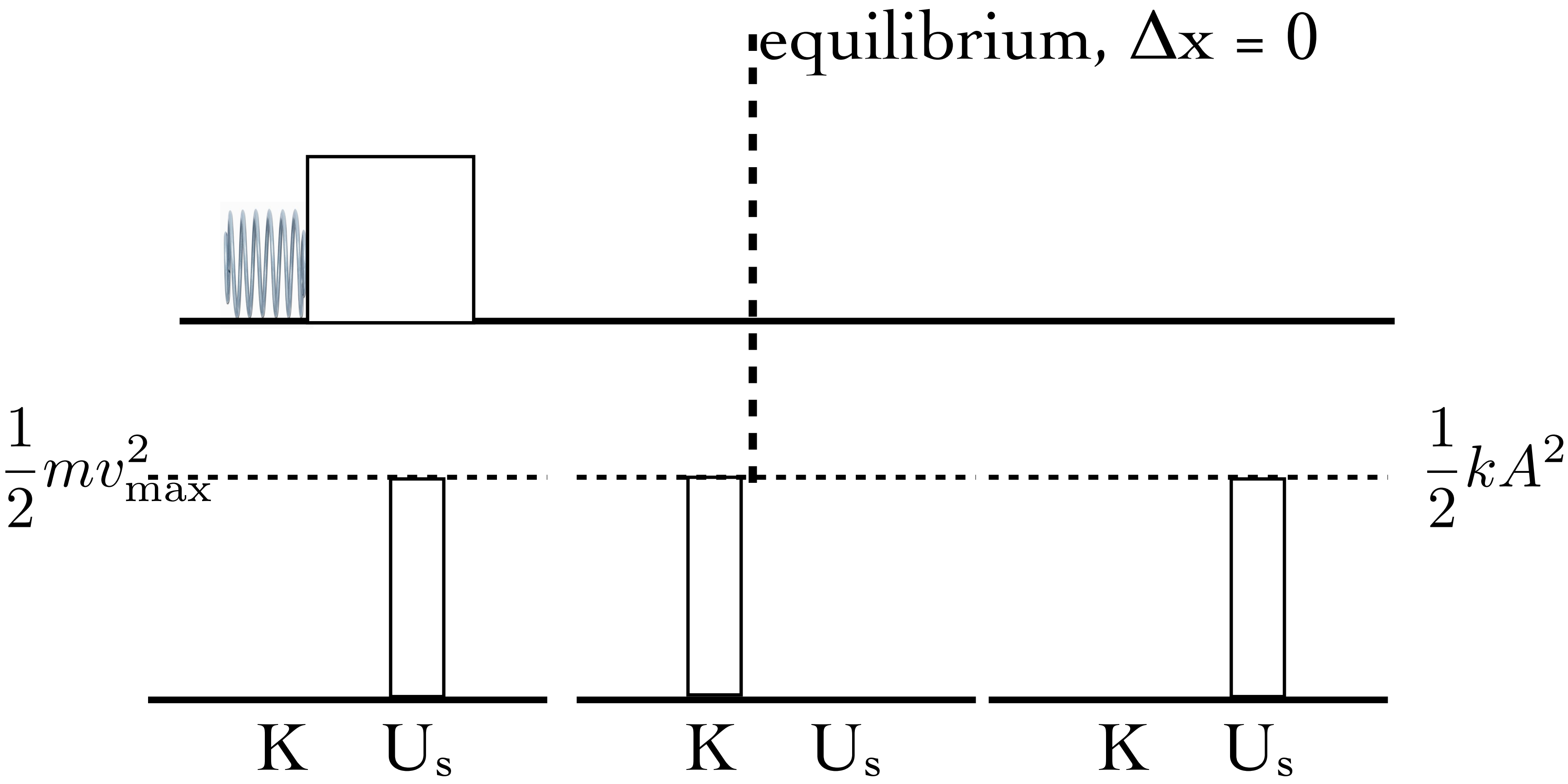
A = Amplitude



Conservation of Energy

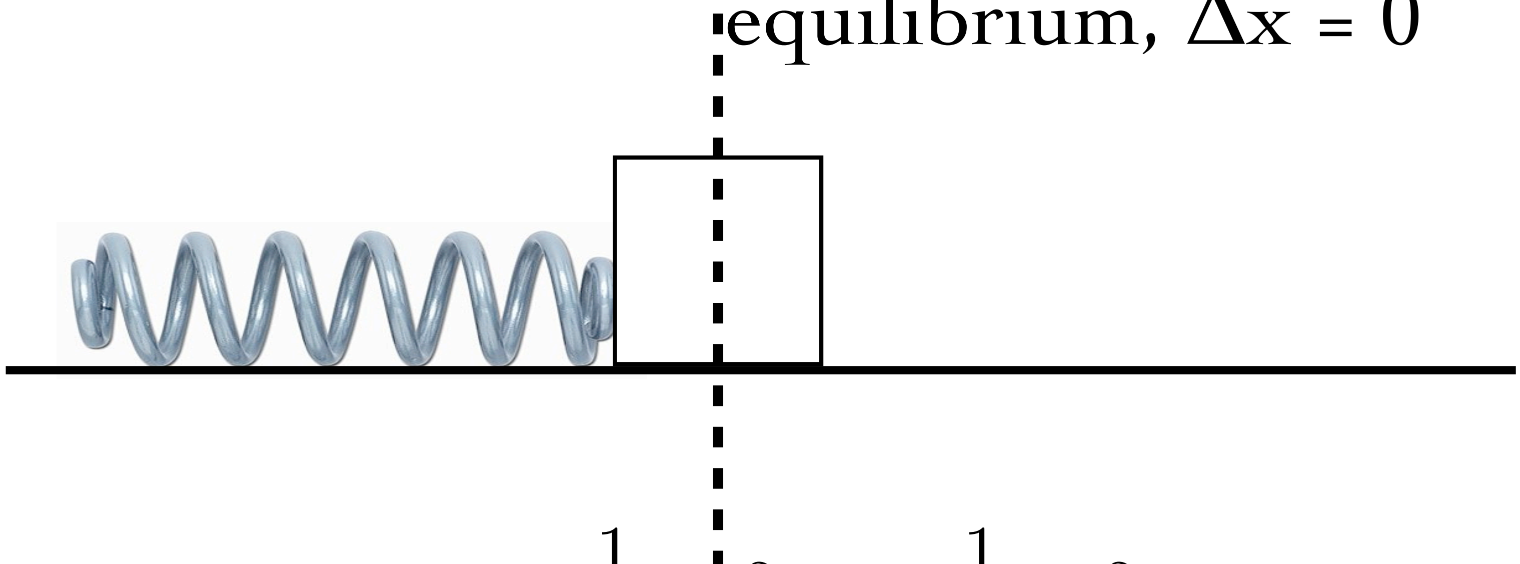
block released from rest

A = Amplitude



Conservation of Energy

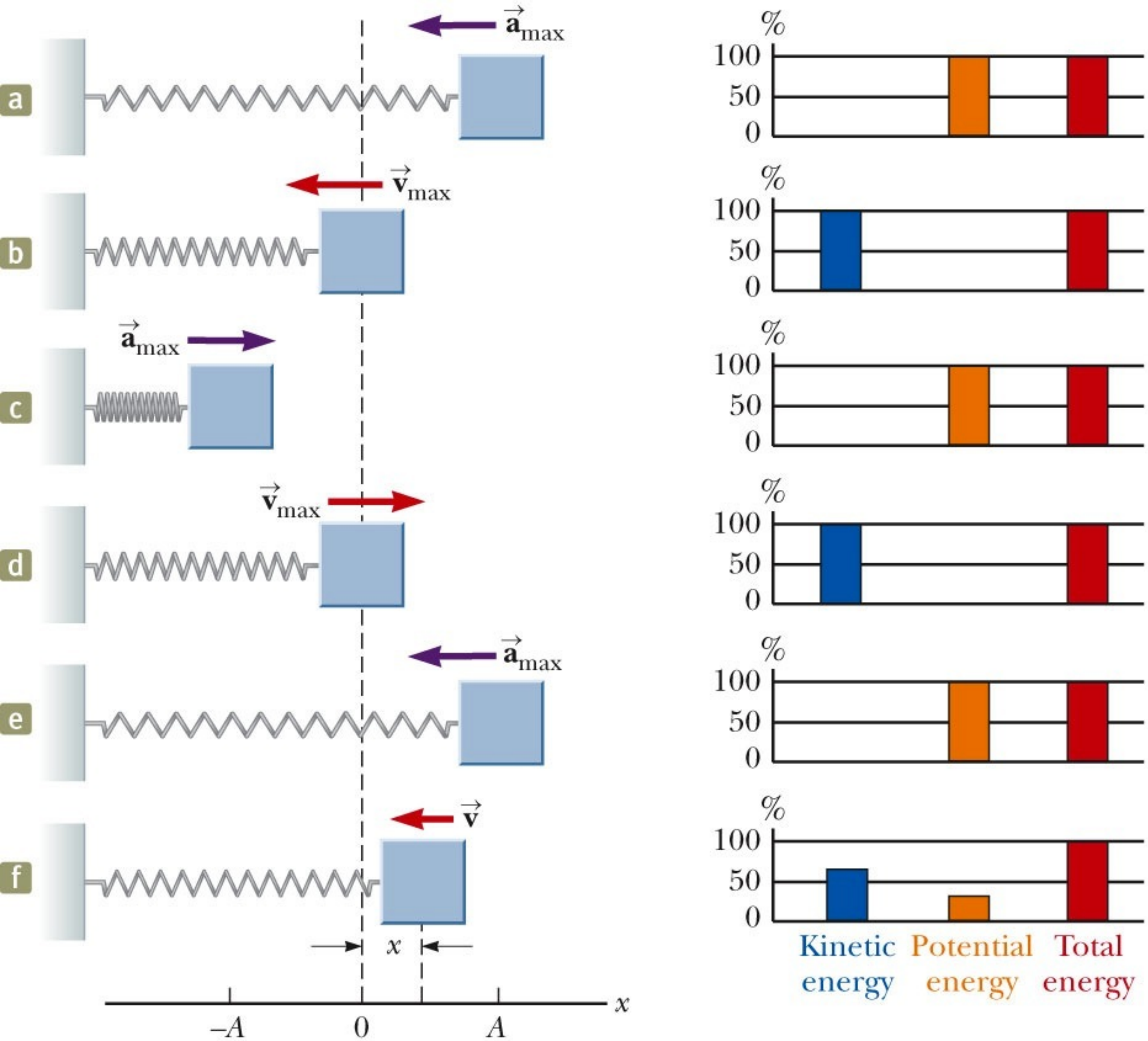
$$K = \frac{1}{2}mv^2 \qquad U_s = \frac{1}{2}k(\Delta x)^2$$



$$E_{\text{total}} = \frac{1}{2}mv_{\text{max}}^2 = \frac{1}{2}kA^2$$

~~kinetic energy = potential energy?~~

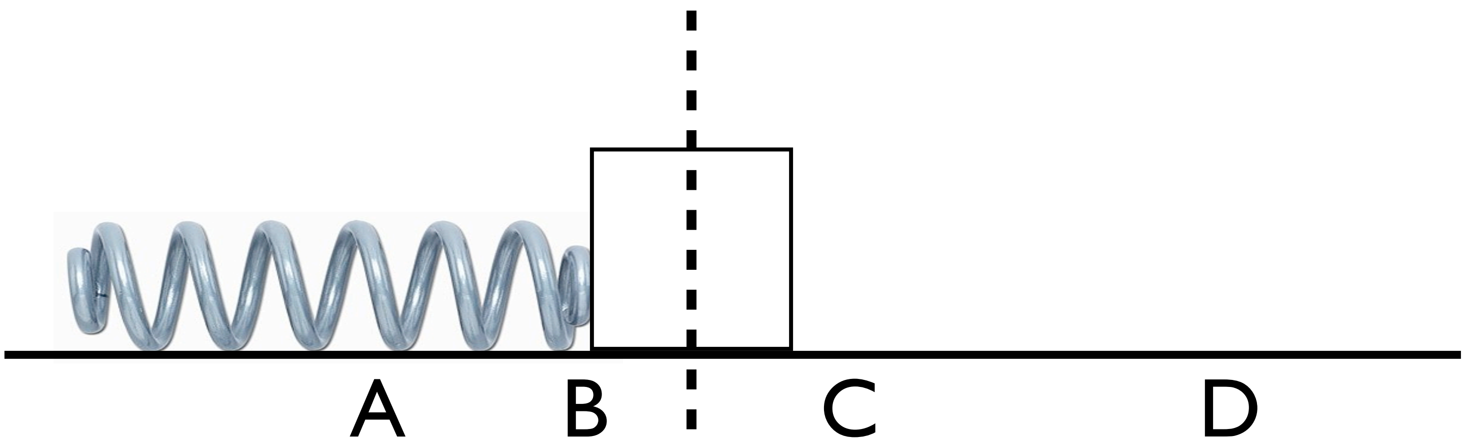
Conservation of Energy



t	x	v	a	K	U
0	A	0	$-\omega^2 A$	0	$\frac{1}{2}kA^2$
$\frac{T}{4}$	0	$-\omega A$	0	$\frac{1}{2}kA^2$	0
$\frac{T}{2}$	$-A$	0	$\omega^2 A$	0	$\frac{1}{2}kA^2$
$\frac{3T}{4}$	0	ωA	0	$\frac{1}{2}kA^2$	0
T	A	0	$-\omega^2 A$	0	$\frac{1}{2}kA^2$
t	x	v	$-\omega^2 x$	$\frac{1}{2}mv^2$	$\frac{1}{2}kx^2$

Conservation of Energy: Example

A mass affixed to the end of a horizontal spring oscillates with amplitude A. When the mass is located at which position below will the potential energy off the mass-spring system be the largest?

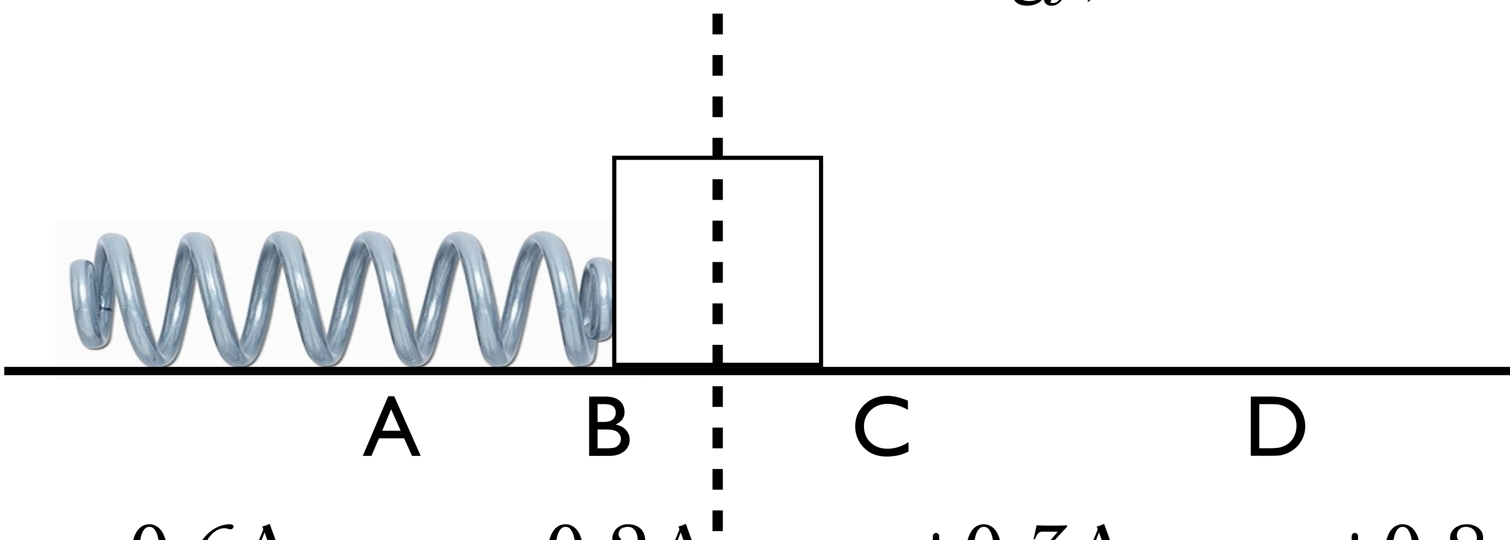


$x_A = -0.6A$ $x_B = -0.2A$ $x_C = +0.3A$ $x_D = +0.8A$

E. All four configurations have the same potential energy

Conservation of Energy: Example

A mass affixed to the end of a horizontal spring oscillates with amplitude A. At which location will the mass have the largest speed? (Hint: think conservation of energy)



$x_A = -0.6A$ $x_B = -0.2A$ $x_C = +0.3A$ $x_D = +0.8A$

E. The speed is the same at all four points

For Monday:

1. go through chapter 12 reading quiz on course website: `ted.ucsd.edu` (backup:`cass.ucsd.edu/~rskibba/`)

2. self-enroll on `www.webassign.net` using our class key (ucsd 2397 3544) and FINISH CHAPTER 12 HOMEWORK if you haven't already

3. make sure you understand: position, velocity, acceleration; frequency and period; force and energy

4. start reading chapter 13 (Mechanical Waves): at least sections 13.1 and 13.2