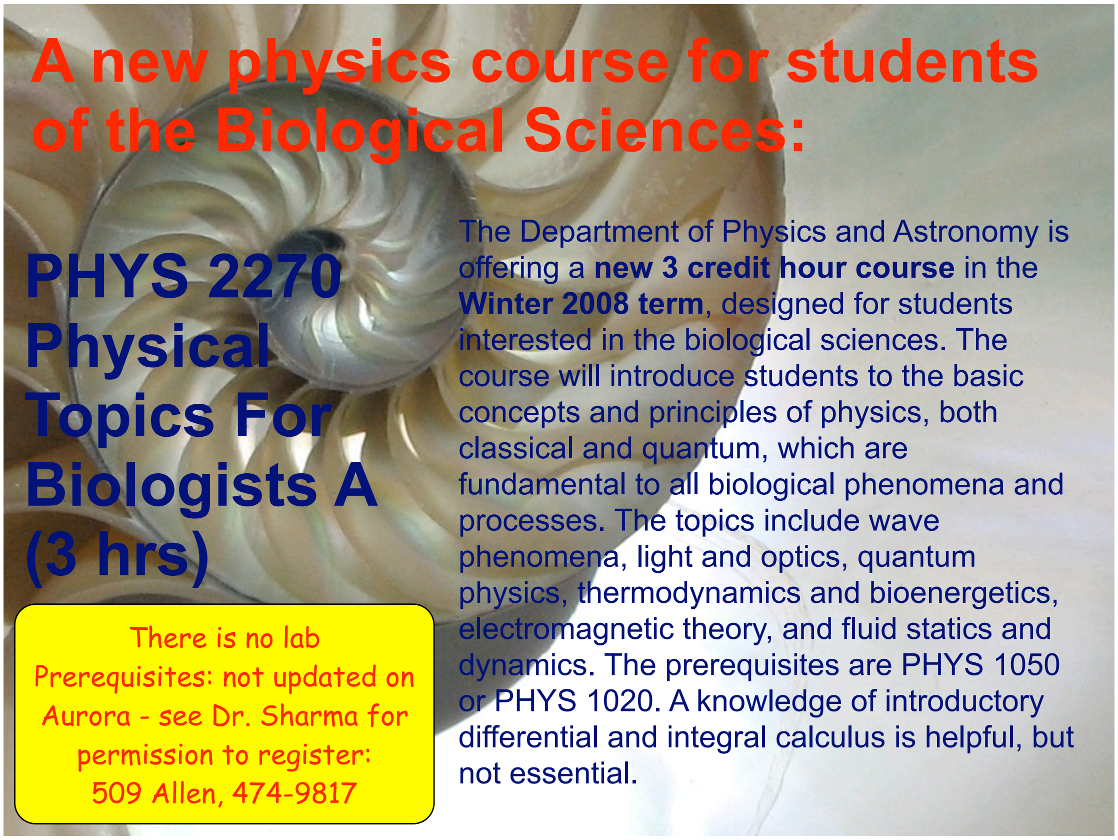


A new physics course for students of the Biological Sciences:

PHYS 2270 Physical Topics For Biologists A (3 hrs)

There is no lab
Prerequisites: not updated on Aurora - see Dr. Sharma for permission to register:
509 Allen, 474-9817

The Department of Physics and Astronomy is offering a **new 3 credit hour course** in the **Winter 2008 term**, designed for students interested in the biological sciences. The course will introduce students to the basic concepts and principles of physics, both classical and quantum, which are fundamental to all biological phenomena and processes. The topics include wave phenomena, light and optics, quantum physics, thermodynamics and bioenergetics, electromagnetic theory, and fluid statics and dynamics. The prerequisites are PHYS 1050 or PHYS 1020. A knowledge of introductory differential and integral calculus is helpful, but not essential.

Mastering Physics Assignment 4

Is due Monday, November 12 at 11 pm

Covers material from chapters 6 and 7

There are 8 questions for practice and 6 for credit

The Final Exam Schedule is Now Final!

PHYS 1020: Monday, December 17, 6 - 9 pm
Frank Kennedy Brown & Gold Gyms
The whole course
30 multiple choice questions
Formula sheet provided

GENERAL PHYSICS I: PHYS 1020

Schedule - Fall 2007
(lecture schedule is approximate)

10	M	5	25	Chapter 10 exclude 10.7 and 10.8	Simple harmonic motion, sections 10.5 and 10.6, for self study only	Tutorial and Test 3 (chapters 6, 7)
	W	7	26			
	F	9	27	Chapter 11 exclude 11.11	Fluids	
11	M	12		Remembrance Day		Experiment 4: Centripetal Force
	W	14	28	Chapter 11 exclude 11.11	Fluids	
	F	16	29			
12	M	19	30	Chapter 12 sections 1 - 8	Temperature and heat (some small sections, notably thermal stress will be omitted)	Tutorial and Test 4 ~~(chapters 9, 10)~~ Chapters 8, 9, 10
	W	21	31			
	F	23	32			

Week of November 12 - holiday on Monday

Experiment 4: Centripetal Force

Week of November 19

Tutorial & Test 4: chapters 8, 9, 10

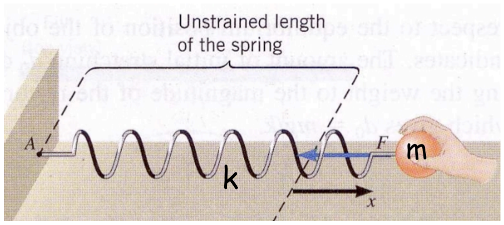
Useful for experiment 4:

10.11/7: A small ball is attached to one end of a spring that has an unstrained length of 0.2 m. The spring is held by the other end, and the ball is whirled around in a horizontal circle at a speed of 3 m/s. The spring remains nearly parallel to the ground and is observed to stretch by 0.01 m. By how much would the spring stretch if it were attached to the ceiling and the ball allowed to hang straight down, motionless?

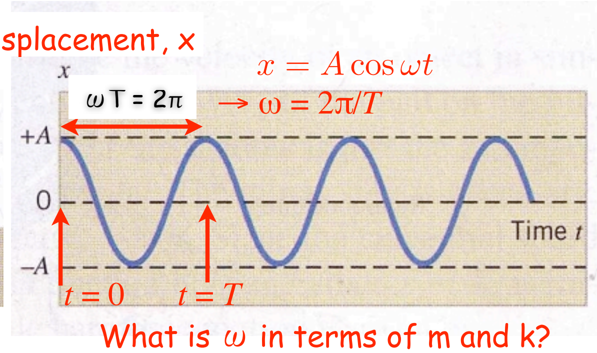
Find the spring constant from the amount the spring stretches when the ball is whirled around in a circle.

→ Find the stretch when the ball is suspended.

Mass on a spring

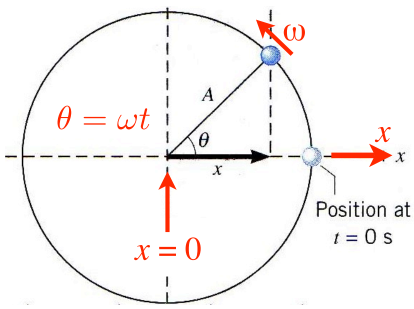


Displacement, x

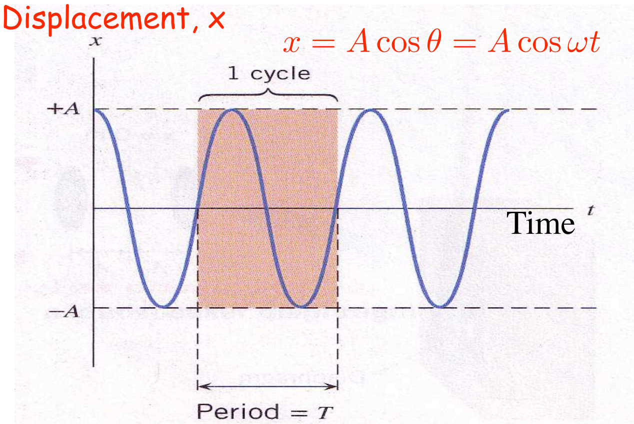


What is ω in terms of m and k?

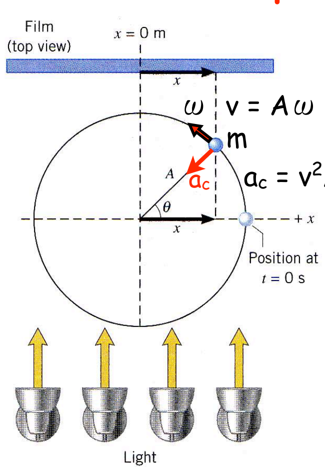
Circular motion

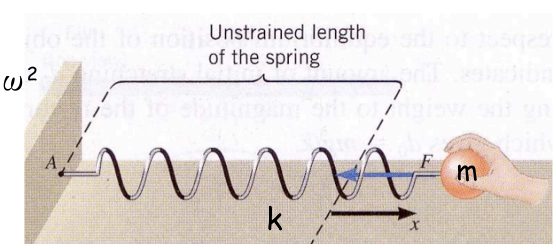


Displacement, x



Simple Harmonic Motion





Mass on a rotating disk
$F_x = -m\omega^2 x$

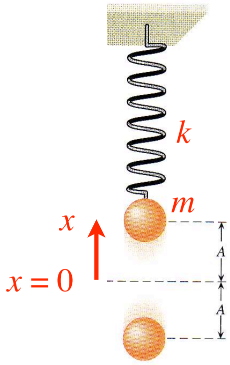
Mass on a spring
$F_x = -kx$

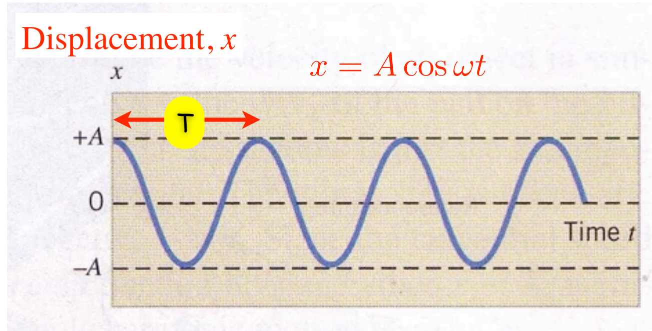
Simple harmonic motion in both cases - restoring force ∝ displacement

COMPARE: if $m\omega^2 = k$, then motions in x are **exactly the same**,

so $\omega^2 = k/m$ for the mass on the spring, and $x = A\cos(\omega t)$

Simple Harmonic Motion





- SHM results when the restoring force is proportional to displacement:

  F = -kx

- The resulting motion is:

$$x = A\cos\omega t, \quad (\text{or } x = A\sin\omega t)$$

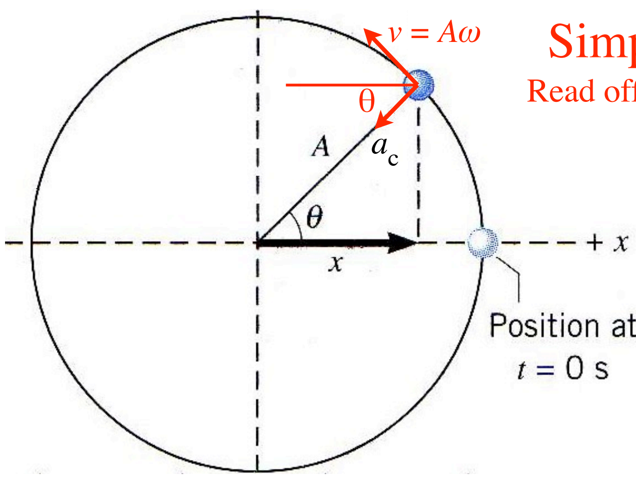
rad/s, Hz, s

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

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

Simple Harmonic Motion

Read off motion from the reference circle



$$\theta = \omega t$$
$$x = A\cos\omega t$$
$$v_x = -A\omega\sin\omega t$$
$$a_x = -A\omega^2\cos\omega t = -\omega^2 x$$

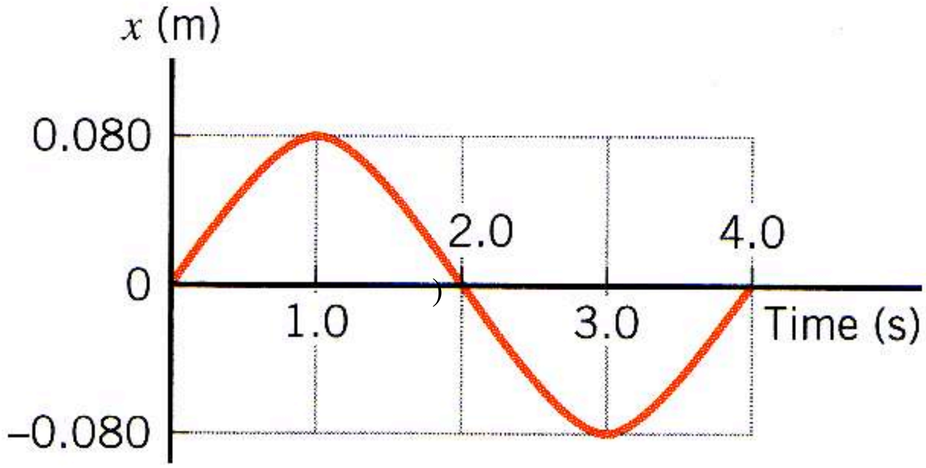
Also by differentiating

$$\text{Maximum } v_x = \pm A\omega \text{ when } x = 0$$

$$\text{Maximum } a_x = \mp A\omega^2 \text{ when } x = \pm A$$

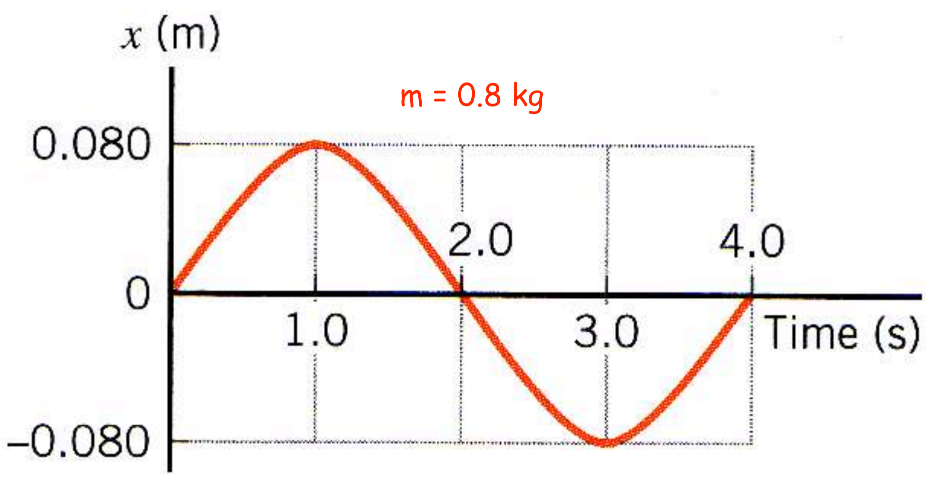
$$\omega = 2\pi f = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$$

10.17: A 0.8 kg mass is attached to a spring.



a) Find the amplitude, A, of the motion.

A = maximum displacement from the equilibrium position = 0.08 m

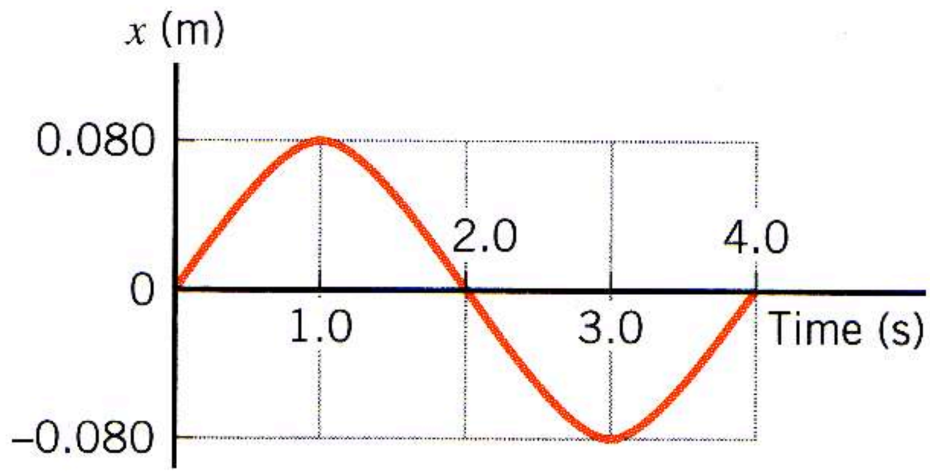


b) Find the angular frequency, ω

$\omega = 2\pi/T$ and T = 4 s, so $\omega = 2\pi/4 = 1.57$ rad/s

c) Find the spring constant, k.

$\omega^2 = k/m$, so $k = m\omega^2 = (0.8\text{ kg})(1.57\text{ rad/s})^2 = 1.97$ N/m



d) Find the speed of the object at t = 1 s.
v = 0 (has reached maximum x and has come momentarily to rest)

e) Find the magnitude of the acceleration at t = 1 s.
$a = -\omega^2 x = -(1.57\text{ rad/s})^2 \times (0.08\text{ m}) = -0.20\text{ m/s}^2$

(Check: $a = F/m = -kx/m = -1.97 \times 0.08/0.8 = -0.20\text{ m/s}^2$)

10.-/20: When a mass m_1 is hung from a vertical spring and set into vertical simple harmonic motion, its frequency is 12 Hz. When another object of mass m_2 is hung on the spring along with m_1, the frequency of motion is 4 Hz. Find m_2/m_1.

$$\omega = \sqrt{k/m} = 2\pi f \qquad \text{that is, } f \propto 1/\sqrt{m}$$

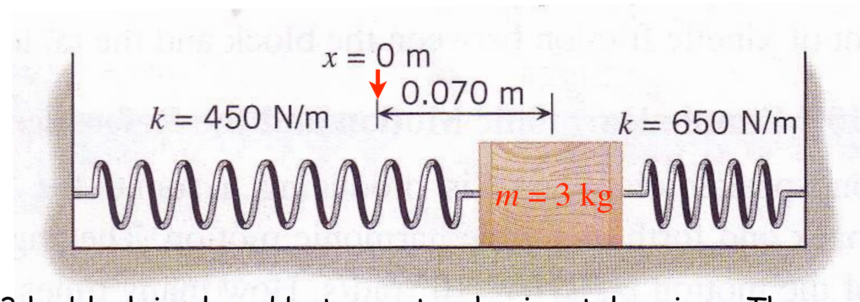
For mass m_1: $f_1 = 12$ Hz

For mass $m_1 + m_2$: $f_2 = 4$ Hz

$$\frac{f_1}{f_2} = \sqrt{\frac{m_1+m_2}{m_1}} = \sqrt{1+m_2/m_1}$$

$$\text{And, } \frac{12}{4} = \sqrt{1+m_2/m_1}$$

$$\frac{m_2}{m_1} = 3^2 - 1 = 8$$



10.22: A 3 kg block is placed between two horizontal springs. The springs are neither strained nor compressed when the block is at x = 0. The block is displaced to x = 0.07 m and is released.

Find the speed of the block when it passes back through x = 0 and the angular frequency of the system.

Question: What is the effective spring constant? That is, what is the restoring force when the block is displaced unit distance?

When the block is moved x to the right, the restoring force is:

$F = -(450 + 650)x = -1100x$ N.

$F = -1100x$ N

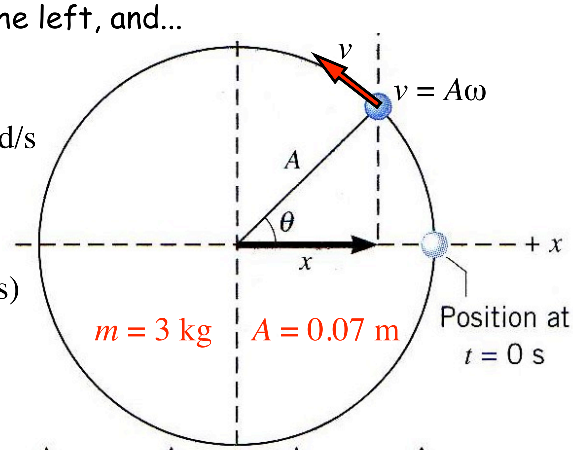
The effective spring constant is 1100 N/m.

When the block passes through x = 0, it has its maximum speed,

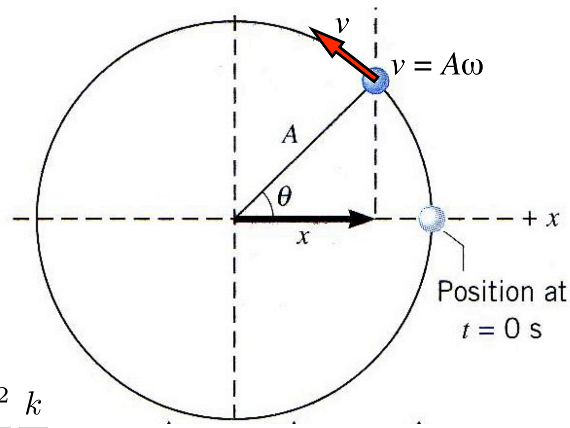
$v_x = -A\omega$ when travelling to the left, and...

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{1100}{3}} = 19.15 \text{ rad/s}$$

$$\text{So, } v_x = -A\omega = -(0.07 \text{ m})\times(19.15 \text{ rad/s}) = -1.3 \text{ m/s}$$



Motion of mass on spring by reference to the reference circle



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

At $x = 0$, $v_x = -A\omega$

The KE of the mass at $x = 0$ is

$$\text{KE} = \frac{mv_x^2}{2} = \frac{mA^2\omega^2}{2} = \frac{mA^2}{2}\frac{k}{m}$$

$$\text{KE} = \frac{kA^2}{2}$$

Conservation of mechanical energy: when the spring is stretched to x = A, it has PE = $kA^2/2$, which is converted entirely to KE when x = 0.

Energy and Simple Harmonic Motion

Elastic Potential Energy:

Energy is stored in a spring when it is stretched or compressed. The potential energy is released when the spring is released.

The restoring force exerted by the spring when stretched by x is:

F = -kx

The work done by the restoring force when the spring is stretched from x_0 to x_f is:

$$W_{elastic} = F_{average} \times (x_f - x_0) = \frac{-k(x_f + x_0)}{2} \times (x_f - x_0)$$

$$W_{elastic} = \frac{-k(x_f + x_0)}{2} \times (x_f - x_0)$$

$$W_{elastic} = \frac{1}{2}kx_0^2 - \frac{1}{2}kx_f^2$$ = work done **by the restoring force**

Initial elastic PE — Final elastic PE

$$PE_{elastic} = \frac{1}{2}kx^2$$

The total mechanical energy is now:

$$E = \frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2$$

Kinetic energy due to rotation could be included too, but we do not cover that.

Mechanical Energy

Elastic Potential Energy:

$$PE_{elastic} = \frac{1}{2}kx^2$$

Mechanical Energy:

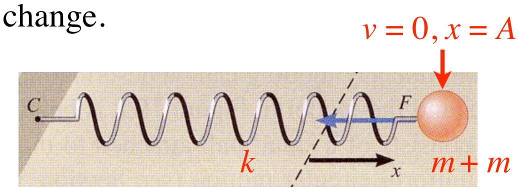
$$\begin{aligned} E &= KE + PE_{grav} + PE_{elastic} \\ &= \frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2 \end{aligned}$$

Mechanical energy is conserved in the absence of nonconservative (applied and friction) forces:

$$W_{nc} = \Delta E = \Delta KE + \Delta PE_{grav} + \Delta PE_{elastic}$$

10.C6: A block is attached to a horizontal spring and slides back and forth in simple harmonic motion on a frictionless horizontal surface. A second identical block is suddenly attached to the first block at the moment the block reaches its greatest displacement and is at rest.

Explain how a) the amplitude, b) the frequency, c) the maximum speed of the oscillation change.



a) Amplitude unchanged

b) $\omega = \sqrt{\dfrac{k}{m}} \rightarrow \sqrt{\dfrac{k}{2m}}$ frequency reduced by factor of $\sqrt{2}$

c) Mechanical energy: at $x = A$: KE = 0, PE = $kA^2/2$ – unchanged

At $x = 0$: $KE_{max} = kA^2/2 = mv_{max}^2/2$ is unchanged

If m is doubled, v_{max} is reduced by factor of $\sqrt{2}$

Mechanical Energy

An object of mass 0.2 kg is oscillating on a spring on a horizontal frictionless table. The spring constant is k = 545 N/m.

The spring is stretched to x_0 = 4.5 cm, then released from rest.

Find the speed of the mass when (a) x_f = 2.25 cm, (b) x_f = 0 cm.

Conservation of mechanical energy: $E_f = E_0$, so

$$\frac{1}{2}mv_o^2 + mgh_o + \frac{1}{2}kx_o^2 = \frac{1}{2}mv_f^2 + mgh_f + \frac{1}{2}kx_f^2$$

$h_f = h_o$ and $v_o = 0$, so:

$$\frac{1}{2}kx_o^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}kx_f^2$$

$$\frac{1}{2}kx_o^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}kx_f^2$$

$$v_f = \sqrt{\frac{k(x_o^2 - x_f^2)}{m}}$$

$x_o = 4.5$ cm, $k = 545$ N/m, $m = 0.2$ kg

(a) $x_f = 2.25$ cm

$$v_f = \sqrt{\frac{545(0.045^2 - 0.0225^2)}{0.2}} = 2.03 \text{ m/s}$$

(b) $x_f = 0$ cm

$$v_f = \sqrt{\frac{545(0.045^2 - 0.0)}{0.2}} = 2.35 \text{ m/s}$$