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.

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
Experiment 4: Centripetal Force
Week of November 19
Tutorial & Test 4: chapters 8, 9, 10

Mechanical Energy

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

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

In the presence of nonconservative forces:

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

10.24: An archer pulls the bowstring back 0.47 m. The bow and string act like a spring with spring constant k = 425 N/m.

What is the elastic potential energy of the drawn bow?

$$E = \frac{1}{2}kx^2 = \frac{1}{2} \times 425 \times 0.47^2 = 46.9 \text{ J}$$

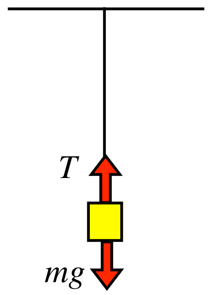
The arrow has a mass m = 0.03 kg. How fast will it travel when it leaves the bow?

$$E = \frac{1}{2}kx^2 + 0 = 0 + \frac{1}{2}mv^2$$

$$46.9 \text{ J} = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.03v^2$$

$$v = \sqrt{2 \times 46.9/0.03} = 55.9 \text{ m/s}$$

10.30: A 3.2 kg block hangs stationary from the end of a vertical spring attached to the ceiling. The elastic potential energy of the spring/mass system is 1.8 J. What is the elastic potential energy when the 3.2 kg mass is replaced by a 5 kg mass?



At equilibrium, mg = T = kx,

where x is the amount the spring is stretched.

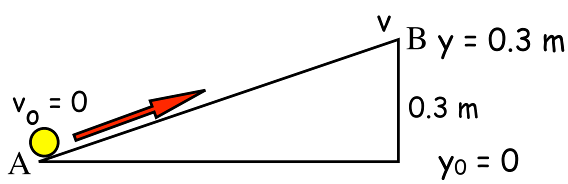
So, x = mg/k.

The elastic potential energy is

$PE_{elastic} = kx^2/2 = k(mg/k)^2/2$.

That is, $PE_{elastic} \propto m^2$
So $PE_{elastic} = (5/3.2)^2 \times 1.8 = 4.4$ J

10.-/26: The spring in a pinball machine (k = 675 N/m) is compressed 0.065 m. The ball (m = 0.0585 kg) is at rest against the spring at point A. When the spring is released, the ball slides to point B, which is 0.3 m higher than point A. How fast is the ball moving at B? (no friction)

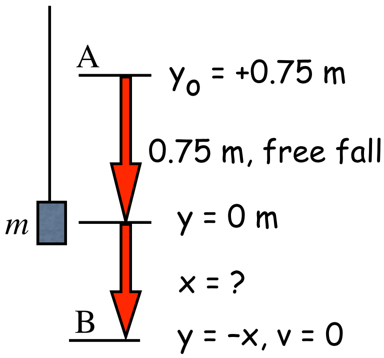


Conservation of mechanical energy:

$$\text{At A: } E_A = \frac{1}{2}mv_0^2 + mgy_0 + \frac{1}{2}kx_0^2$$
$$= 0 + 0 + \frac{1}{2} \times 675 \times 0.065^2 = 1.426 \text{ J}$$

$$\text{At B: } E_B = \frac{1}{2}mv^2 + 0.3mg + 0 = 1.426 \text{ J} \rightarrow v = 6.55 \text{ m/s}$$

10.76/34: An 86 kg climber is scaling the vertical wall of a mountain. His safety rope when stretched acts like a spring with spring constant k = 1200 N/m. He falls 0.75 m before the rope becomes taut. How much does the rope stretch when it breaks his fall and momentarily brings him to rest?



Mechanical energy is conserved:

At A: $E = mgy_0$

At B: $E = mgy + kx^2/2$
$= -mgx + kx^2/2$

So, $mgy_0 = -mgx + kx^2/2$

$kx^2/2 - mgx - mgy_0 = 0$

$$\text{so, } x = \frac{mg \pm \sqrt{m^2g^2 + 2kmgy_0}}{k}$$

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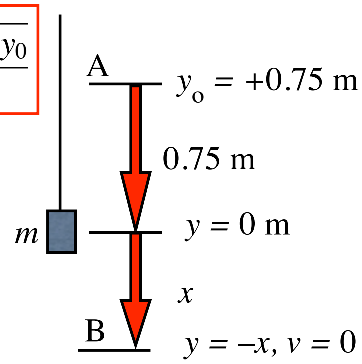
$$x = \frac{86g \pm \sqrt{86^2g^2 + 2 \times 1200 \times 86g \times 0.75}}{1200}$$



x = 1.95 m, or −0.54 m, corresponding to:

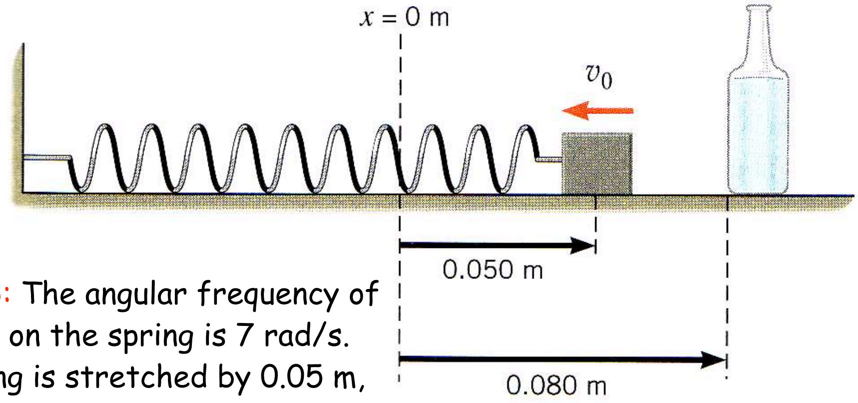
so, y = −x = −1.95 m, or +0.54 m.

y = +0.54 m means the rope is stretched by a negative amount!

So, y = −1.95 m and the rope is stretched 1.95 m

The angular frequency of the climber on the end of the rope is

$$\omega = \sqrt{k/m} = \sqrt{(1200 \text{ N/m})/(86 \text{ kg})} = 3.74 \text{ rad/s} \qquad (T = 1.7 \text{ s})$$



10.34/76: The angular frequency of the mass on the spring is 7 rad/s. The spring is stretched by 0.05 m, as shown, and the block is thrown to the left.

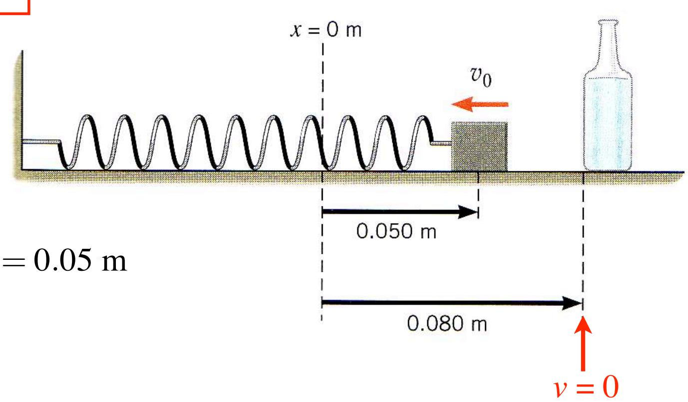
Find the minimum speed v_0 so that the bottle gets hit (ignore width of block).

Conservation of mechanical energy:

$$PE_0 + KE_0 = PE + KE$$

$$PE_0 + KE_0 = PE + KE$$

$\omega = 7$ rad/s



$$PE_o = \frac{1}{2}kx_o^2, \text{ with } x_o = 0.05 \text{ m}$$

$$KE_o = \frac{1}{2}mv_o^2$$

$$PE = \frac{1}{2}kx^2, \text{ with } x = 0.08 \text{ m}$$

$$KE = 0 \text{ (just reaches the bottle)}$$

$$\frac{1}{2}k \times 0.05^2 + \frac{1}{2}mv_o^2 = \frac{1}{2}k \times 0.08^2 + 0$$

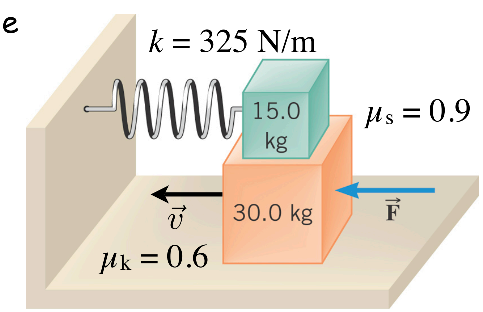
$$\frac{1}{2}k \times 0.05^2 + \frac{1}{2}mv_o^2 = \frac{1}{2}k \times 0.08^2 + 0$$

$$\omega = \sqrt{\frac{k}{m}} = 7 \text{ rad/s}, \text{ so}, k = 49m$$

$$\text{Therefore}, mv_0^2 = 49m(0.08^2 - 0.05^2)$$

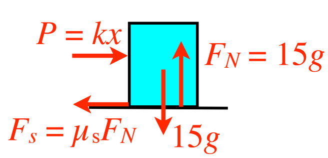
$$v_0 = 0.44 \text{ m/s}$$

10.12: A horizontal force F is applied to the lower block in such a way that the blocks move at constant speed. At the point where the upper block begins to slip, determine a) the amount by which the spring is compressed and b) the magnitude of the force, F.



There is no acceleration, so the net force on each block is zero.

a) Forces on the upper block:

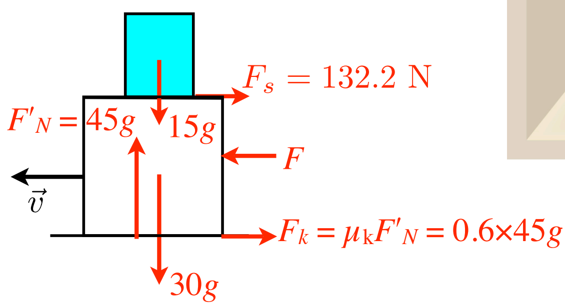


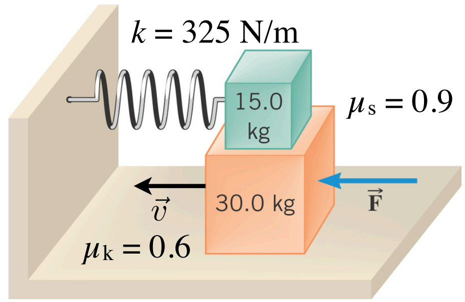
Block slips when P = $(F_s)_{max} = \mu_s F_N$

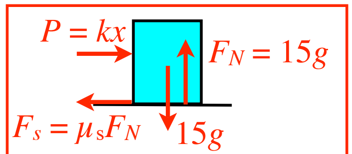
That is: kx = $\mu_s \times 15g$ $\quad \rightarrow x = \frac{15\mu_s g}{k} = \frac{15 \times 0.9g}{325} = 0.407$ m

and $F_s = 15\mu_s g = 132.2$ N

b) Forces on the lower block:







Forces on the upper block

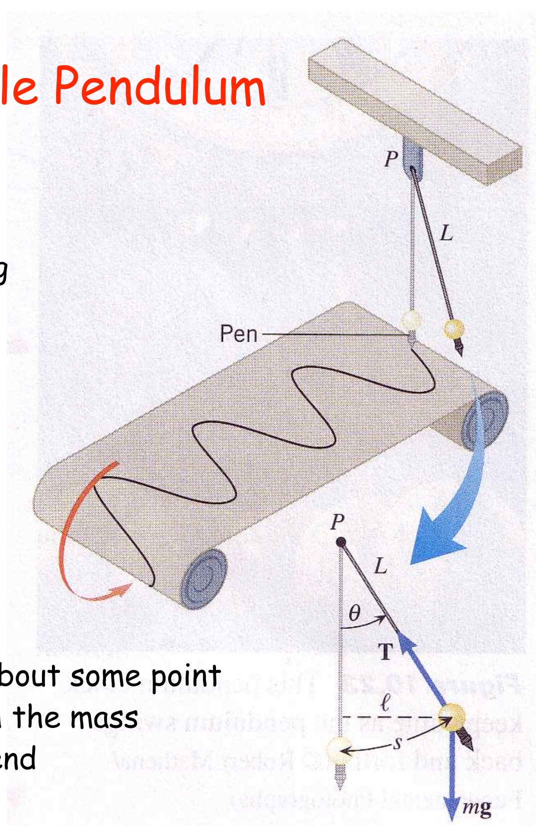
Acceleration = 0, so net force on block = 0

$$F = F_s + F_k = 132.2 + 0.6 \times 45g = 397 \text{ N}$$

The Simple Pendulum

Simple Pendulum:

- a mass on the end of a string
- executes SHM for small displacements



"Physical Pendulum"
(not covered)
– an extended mass pivoting about some point
– example, a solid bar in which the mass is not concentrated at one end

Simple Pendulum

The restoring force along the arc s along which the mass moves is:

$F = -mg\sin\theta \simeq -mg\theta$ for small angles

and $\theta = \frac{s}{L}$ radians

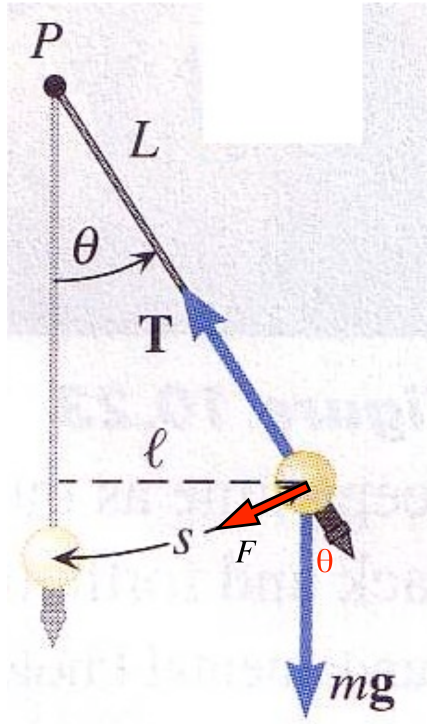
So, $F = -\left(\frac{mg}{L}\right)s$

Force pulls mass back to $\theta = 0$

This is of the same form as for a mass on a spring:

F = -kx, with s taking the place of x and with an effective spring constant:

k = mg/L



Effective spring constant, $k = mg/L$

Then, the angular frequency for the motion is:

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

As, $\omega = 2\pi f = 2\pi/T$, the period is

$$T = 2\pi\sqrt{\frac{L}{g}}$$ Period of a simple pendulum

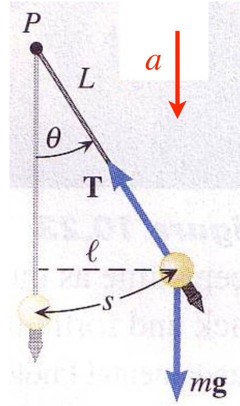
"Physical pendulum": an extended object pivoting about a point

Not covered!

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

I = moment of inertia
L = distance from pivot to centre of gravity

Clickers!



You have a simple pendulum in an elevator that is accelerating downward with acceleration a.

Does the pendulum swing more slowly, more quickly, or at the same rate as it does when the elevator is at rest?

A) The pendulum swings more slowly

B) The pendulum swings more quickly

C) The pendulum swings at unchanged rate

The tension in a string from which a mass is suspended is m(g - a), as if the acceleration due to gravity has been reduced...

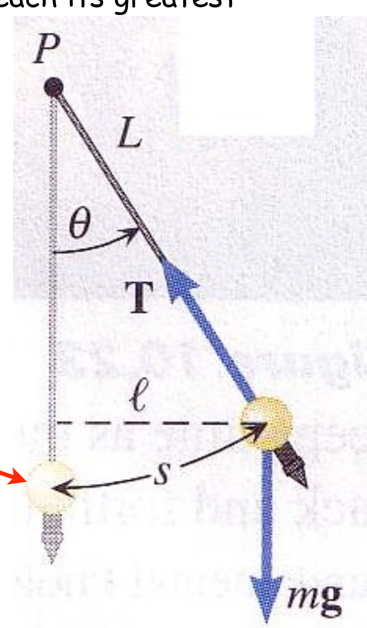
10.40: A pendulum consists of a ball on the end of a string 0.65 m long. The ball is pulled to one side through a small angle and released. How long does it take the ball to reach its greatest speed?

Conservation of mechanical energy:

$$PE_o + KE_o = PE + KE, \text{ or}$$

$$PE_o + 0 = 0 + KE$$

At lowest point, PE = 0, so KE = maximum value



Time to reach lowest point is T/4:

$$t = \frac{1}{4} \times 2\pi\sqrt{L/g} = 0.40 \text{ s}$$

10.-/42: A pendulum clock acts as a simple pendulum of length 1 m. It keeps accurate time at a location where the acceleration due to gravity is 9.83 m/s^2. What must be the length of the pendulum to keep accurate time if the local acceleration due to gravity is 9.78 m/s^2?

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

For a fixed period, L/g = constant.

$$\text{So, } \frac{L_1}{g_1} = \frac{L_2}{g_2} \text{ to keep time}$$

$$L_2 = L_1 \times \frac{g_2}{g_1} = (1\ \text{m}) \times \frac{9.78}{9.83}$$

$$L_2 = 0.995\ \text{m}$$

10.69/41: Astronauts on a distant planet set up a simple pendulum of length 1.2 m. The pendulum executes simple harmonic motion and makes 100 complete swings in 280 s. What is the acceleration due to gravity on the planet?

$$\text{Period, } T = 2\pi\sqrt{\frac{L}{g}} = \frac{280}{100} = 2.8\ \text{s}$$

$$g = L\left[\frac{2\pi}{T}\right]^2 = 1.2\left[\frac{2\pi}{2.8}\right]^2 = 6.0\ \text{m/s}^2$$

Simple Harmonic Motion

- The restoring force has the form: F = –kx
- The motion is: x = A cos(ωt), or x = A sin(ωt)
- The angular frequency is: $\omega = \sqrt{\frac{k}{m}}$

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

- Simple pendulum:

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