Hour Exam III answers posted on the website
Earlier Hour Exam answers also posted.

Exam grades posted on Tycho. Average was only 39 ! We will go over the exam Friday.

Office hrs NOT WED, but Thurs and Fri (normal) from 4pm to 5:30 or so.

Final homework assignment due Friday Dec 7

Final exam Monday Dec 10 at 0830 here.

Exam has M.C and work out problem by me
M.C and workout problem by Tutorial people
M.C problem from lab. Lab problem based on labs you did and *don't forget uncertainty analysis*.

Simple Harmonic Motion summary

Had $\frac{d^2x(t)}{dt^2} = -\frac{k}{m}x(t)$ for mass on spring

Most general solution is

$$x(t) = A\sin(\omega t) + B\cos(\omega t)$$

$$\omega = +\sqrt{k/m}$$

with A and B chosen to give the right x(0) and v(0).

Other ways to write it:

$A_s \sin(\omega t + \phi_s)$ or $A_c \cos(\omega t + \phi_c)$

now the two adjustable parameters are *A* and ϕ

Textbook uses $A\cos(\omega t + \phi_c)$

Amplitude: $|A_s|$ or $|A_c|$ or $\sqrt{A^2 + B^2}$

Phase: ϕ

Angular frequency: ω

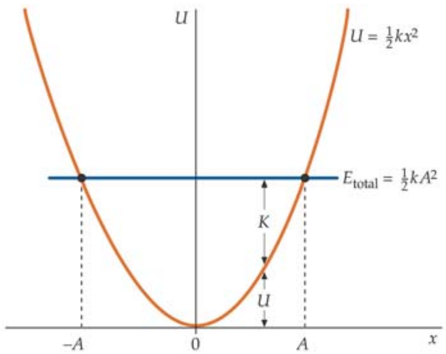
Period $T = 2\pi/\omega$

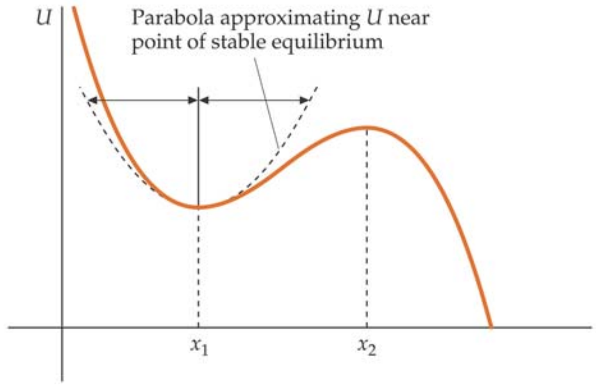
Frequency ***f=1/T*** (Note error in text eqn 14-11.)

$$\omega = 2\pi\frac{1}{T} = 2\pi f$$ is correct.

Energy in S.H.M. $E = \frac{1}{2}kx^2 + \frac{1}{2}mv^2 = \frac{A^2k}{2}$

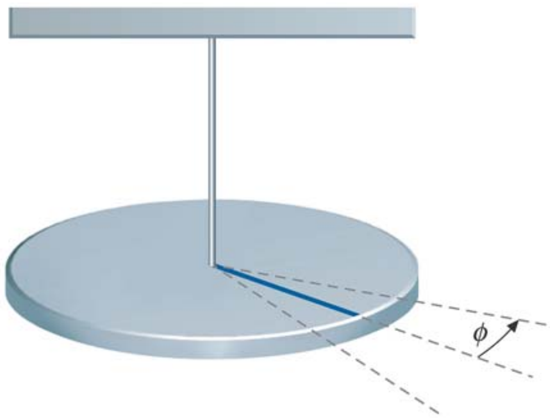
Use of S.H.O. for general physical problem:





Equilibrium point in $U(x)$ is at a minimum at x_1.
Expand $U(x)$ about x_1 with Taylor expansion.
First derivative of $U(x)$ is 0 at a minimum so get
$U(x_1) + \Delta x^2[d^2U/dx^2](1/2) + \ldots$ for small amplitudes.
This is a spring with $k = [d^2U/dx^2]$
Examples – molecules, nuclei, anything that vibrates.

Other examples of S.H.O

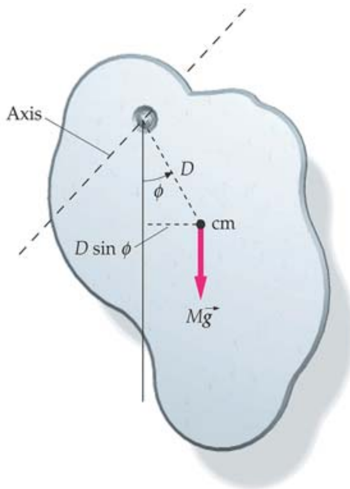


Torsion pendulum (like in Cavendish expt.)

Object with I hanging on a wire with κ
so $\tau = -\kappa\phi = I\alpha$
(like mass on spring)

Thus motion is given by
$\phi(t) = A\cos(\omega t + \phi_0)$ with $\omega = \sqrt{\kappa / I}$
This is how you get κ which you need to get G with the Cavendish experiment.

Physical Pendulum:
Torque about axis
$\tau = -MgD\sin(\phi)$
Need to know I
$\tau = I\alpha$ **and** $\alpha = d^2\phi/dt^2$



$$-MgD\sin(\phi) = I\frac{d^2\phi}{dt^2}$$

Not the same equation. Have sin(ϕ), not ϕ

Expand about 0: $\sin(x) = x - x^3/6 + \ldots$

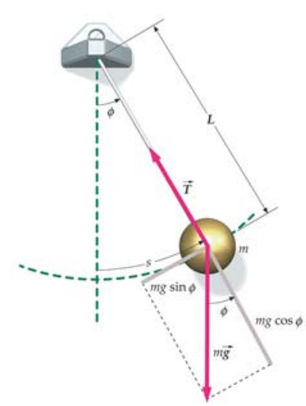
replace sin(ϕ) with ϕ to get $\dfrac{d^2\phi}{dt^2} = -\dfrac{MgD}{I}\phi$

good for small amplitudes only

So $\omega = \sqrt{\dfrac{MgD}{I}}$ **Note** ***M/I***

does not depend on M.

Simple Pendulum: Small sized mass on string.
D* becomes *L



I **is** ML^2 **so** $\omega = \sqrt{\dfrac{g}{L}}$ **This**

is used to compare g at different locations.
Clicker

Both a mass–spring system and a simple pendulum have a period of 1 s. Both are taken to the moon in a lunar landing module. While they are inside the module on the surface of the moon,

A. the pendulum has a period longer than 1 s.
B. the mass–spring system has a period longer than 1 s.
C. both A and B are true.
D. the periods of both are unchanged.
E. one of them has a period shorter than 1 s

If the length of a simple pendulum is increased by 4% and the mass is decreased by 4%, the period is

A. not changed.
B. increased by 2%.
C. decreased by 4%.
D. increased by 4%.
E. decreased by 2%.

Damping

If a force is proportional to – *v* it will slow the oscillator. This also makes a solvable differential equation. $\frac{d^2x(t)}{dt^2} = -\frac{k}{m}x(t) - \frac{b}{m}\frac{dx}{dt}$

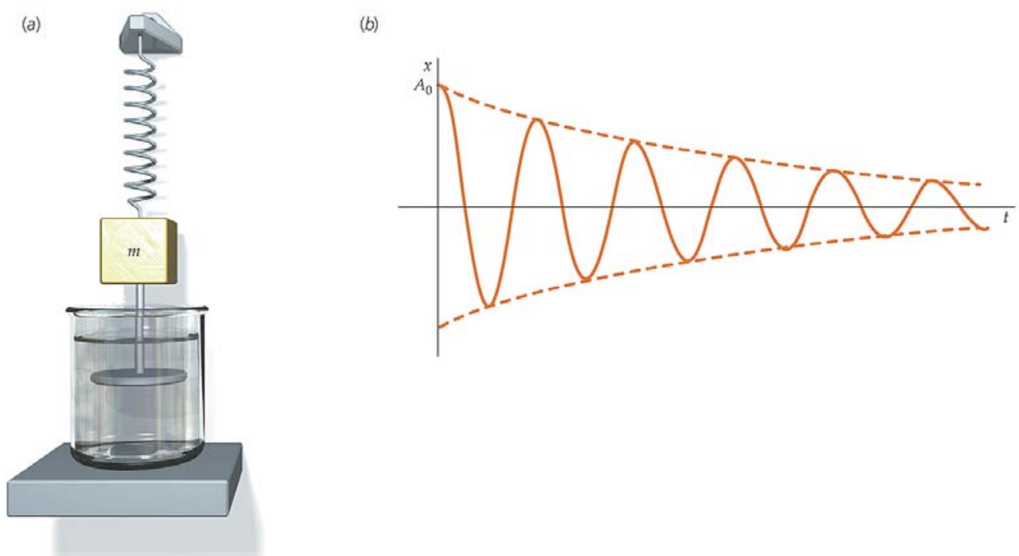
Note that *b/m* has dimensions 1/time. The time τ = *m*/*b* is the "damping time" and the system energy drops by 1/e in that time. (this τ is time, not torque – sorry.) Note small *b* is long τ

Solution, if τ >T (actually $\tau > 1/(2\omega_0) = T/4\pi$)

$$x(t) = A_0 e^{-t/2\tau}\cos(\omega' t + \phi)$$ **where**

$$\omega' = \omega_0\left(1 - \frac{1}{(2\omega_0\tau)^2}\right)$$ **and** $$\omega_0 = \sqrt{k/m}$$

for large τ frequency is not shifted much.



If $2\omega_0\tau$ = 1, then ω' = 0 and the system does not oscillate. Critically damped.
$2\omega_0\tau$ = 1 → $b_c = 2\omega_0 m$ gives critical, and bigger b gives "over damping"