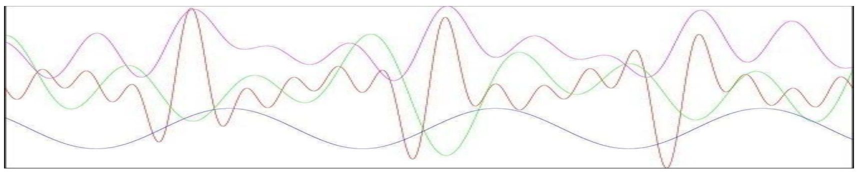
Music, Math, and Motion

with Dr. Arun Chandra & Dr. E.J. Zita
The Evergreen St. College



Winter week 2
Friday 16 Jan. 2009

Ch.11: Vibrations & waves

- Where to find our Giancoli physics online
- Overview of 11# 1, 2, 3, 5
- Jigsaw learning plan today
- Choose homework together, due next Friday
- Looking ahead

Where to find our Giancoli physics online

2 **Week 2: 12 January - 18 January**

Our Moodle workshop on Thursday in the CAL (1st floor Lab I) is required even if you already know Moodle (then you can be one of our expert assistants). You will register & login, post your self-description, and learn to respond online. You will find teammates to work with and post your first team assignment online.

You will post many of your assignments on Moodle this quarter, individually or in teams. Agree today (or tomorrow at the latest) on a time and place that your team will meet this weekend. You will pre-seminar together and post your first PIQs: Points, Insights, and Questions.

Self-descriptions and Groups (winter)

Physics chapters

Overview of 11 #1: Simple Harmonic Motion (SHM)

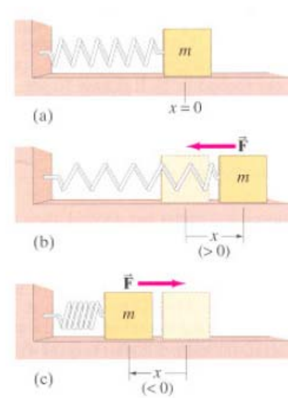


FIGURE 11–1 A mass vibrating at the end of a uniform spring.

F = -kx, where k = spring constant

F = force on mass,

x = displacement from equilibrium

Overview of 11 #2: Energy in the Simple Harmonic Oscillator

Potential Energy = ½ kx^2

Kinetic Energy = ½ mv^2

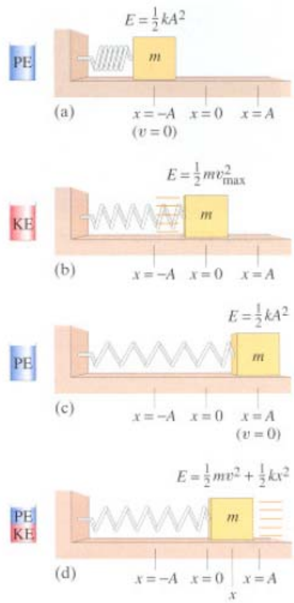
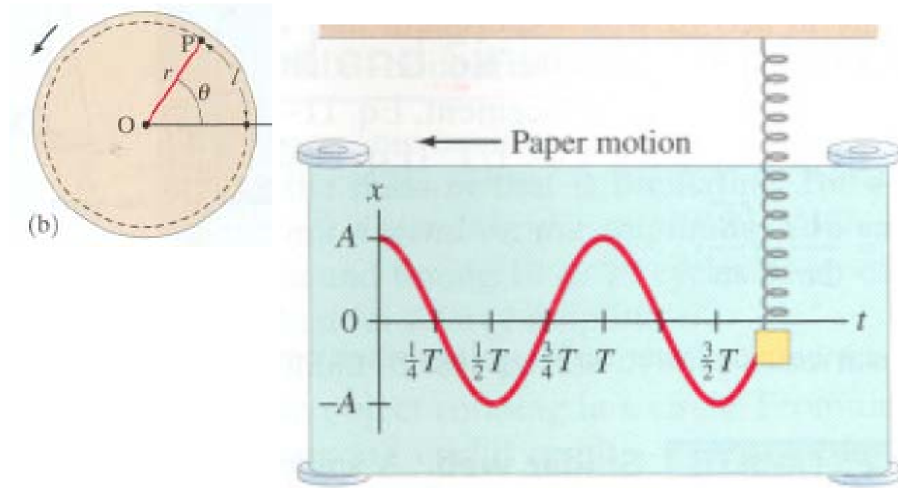


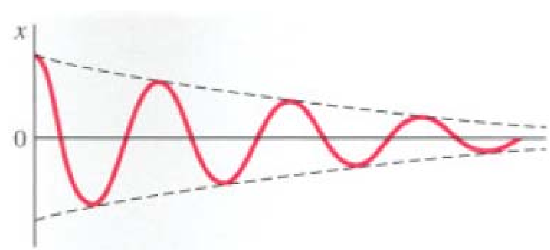
FIGURE 11–5 Energy changes from potential energy to kinetic energy and back again as the spring oscillates.

Overview of 11 #3: The period and sinusoidal nature of SHM



$$x(t) = A\cos(\omega t) = A\cos(2\pi f\, t)$$

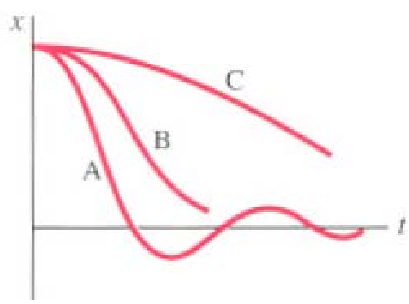
Overview of 11 #5: Damped Harmonic Motion



C: underdamped

B: Critically damped

A: overdamped

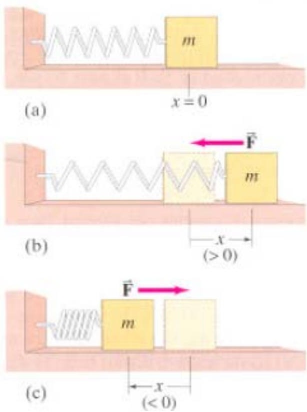


Jigsaw learning-through-discussion

1. Count off by 1, 2, 3, 5
- Each team read and discuss your section
- Identify key points
- Zita will circulate, answering questions

2. Mix teams so there is one expert for each chapter on each team
- Discuss all sections – share your key points

3. Whole group gather: resolve questions, share insights, and choose homework together



More on Ch.11 #1: SHM

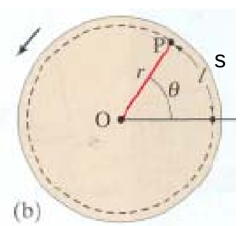
$$\text{angular displacement} = s = r\theta$$

$$\text{speed} = v = \frac{s}{t} = r\frac{\theta}{t} = r\omega$$

$$v = \frac{\text{distance}}{\text{time}} = \frac{\text{circumference}}{\text{period}} = \frac{2\pi}{T}$$

$$\text{angular frequency } \omega = \frac{2\pi}{T} = 2\pi f$$

$$\text{frequency } f = \frac{1}{T} \text{ where } T = \text{period}$$



More on Ch.11 #2: Energy

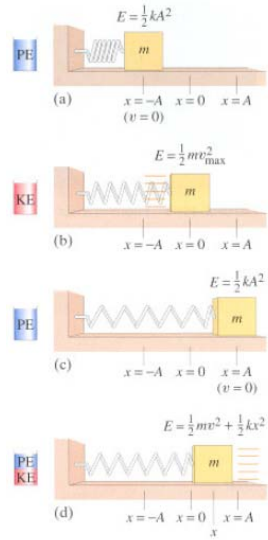


FIGURE 11–5 Energy changes from potential energy to kinetic energy and back again as the spring oscillates.

As the mass oscillates back and forth, the energy continuously changes from potential energy to kinetic energy, and back again (Fig. 11–5). At the extreme points, $x = -A$ and $x = A$ (Fig. 11–5a, c), all the energy is stored in the spring as potential energy (and is the same whether the spring is compressed or stretched to the full amplitude). At these extreme points, the mass stops momentarily as it changes direction, so $v = 0$ and

$$E = \tfrac{1}{2}m(0)^2 + \tfrac{1}{2}kA^2 = \tfrac{1}{2}kA^2. \qquad \textbf{(11–4a)}$$

Thus, the **total mechanical energy of a simple harmonic oscillator is proportional to the square of the amplitude**. At the equilibrium point, $x = 0$ (Fig. 11–5b), all the energy is kinetic:

$$E = \tfrac{1}{2}mv_{max}^2 + \tfrac{1}{2}k(0)^2 = \tfrac{1}{2}mv_{max}^2, \qquad \textbf{(11–4b)}$$

where v_{max} represents the *maximum* velocity during the motion (which occurs at $x = 0$). At intermediate points (Fig. 11–5d), the energy is part kinetic and part potential; because energy is conserved (we use Eqs. 11–3 and 11–4a),

$$\tfrac{1}{2}mv^2 + \tfrac{1}{2}kx^2 = \tfrac{1}{2}kA^2. \qquad \textbf{(11–4c)}$$

From this conservation of energy equation, we can obtain the velocity as a function of position. Solving for v^2, we have

$$v^2 = \frac{k}{m}(A^2 - x^2) = \frac{k}{m}A^2\left(1 - \frac{x^2}{A^2}\right).$$

From Eqs. 11–4a and 11–4b, we have $\frac{1}{2}mv_{max}^2 = \frac{1}{2}kA^2$, so $v_{max}^2 = (k/m)A^2$.

Force → Energy → Power

Mechanical energy = Work = Force * displacement

Mechanical energy = Kinetic Energy + Potential Energy

Kinetic Energy = ½ mv^2 *Potential energy = ability to do work…*

Units of Energy: Force (N) * Displacement (m) = Joules = N*m

Power = rate of doing work = Energy / time

$$\text{Units of Power}: \frac{\text{Energy}}{\text{time}}\left(\frac{\text{Joules}}{\text{seconds}}\right) = \textbf{Watts} = \frac{kg\, m^2/s^2}{s} = \frac{kg\, m^2}{s^3}$$

More on Ch.11 #3: Sinusoidal oscillations

$$\text{time (seconds)}, \text{Period} = T(s)$$

$$\text{frequency} = f\left(\frac{1}{s}\right) = (\text{Hertz}) = (Hz), \qquad f = \frac{1}{T}$$

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \text{distance} = x(\text{meters})$$

$$v = \frac{x}{t}, \quad v\left(\frac{m}{s}\right) = \frac{x(m)}{t(s)}$$

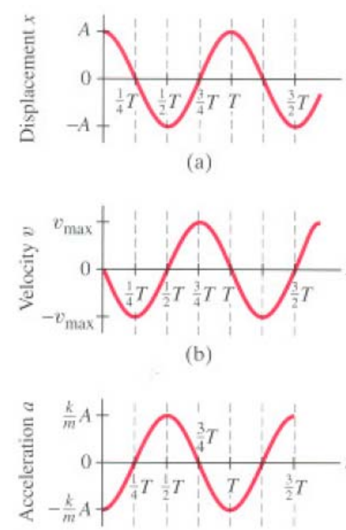
$$\text{acceleration} = \text{rate of change of speeed} = \frac{\text{speed}}{\text{time}}$$

$$a = \frac{v}{t}, \quad a\left(\frac{m}{s^2}\right) = \frac{v\left(m/s\right)}{t(s)}$$

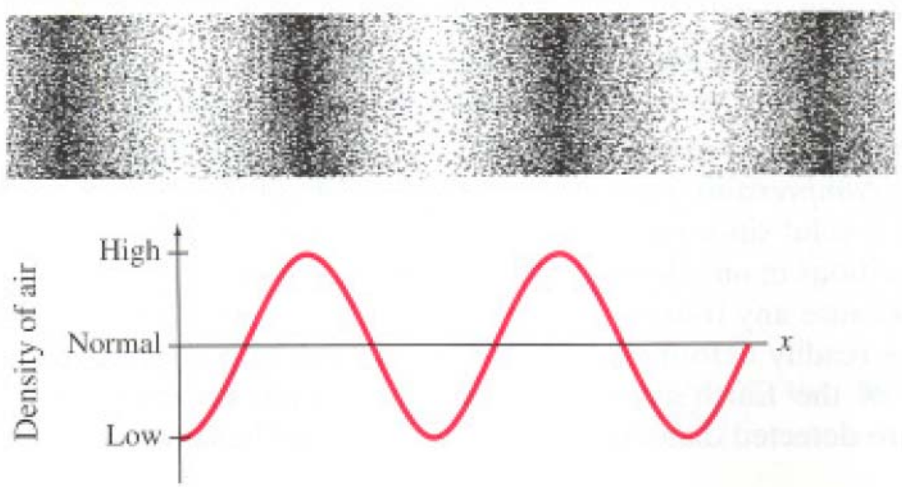
$$\text{Force} = \text{mass} * \text{acceleration}, \quad \text{mass}(kg)$$

$$F = ma, \quad F(N) = m(kg) * a\left(\frac{m}{s^2}\right)$$

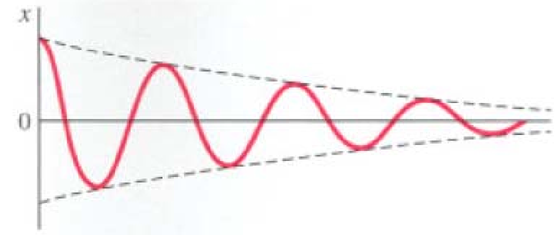
$$\text{Force units}: N = \text{Newtons} = \frac{kg\, m}{s^2}$$



Example of SHM: Acoustic waves



More on Ch.11#5: Damped Harmonic Motion



Does oscillation frequency depend on damping?

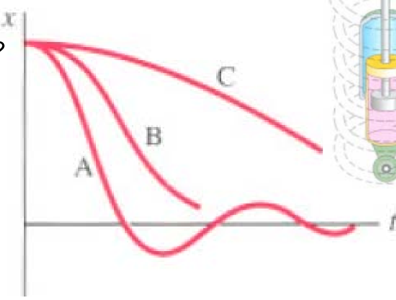
Are any of these name surprising?

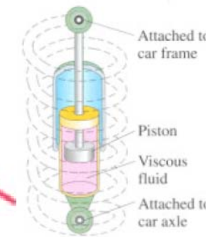
C: underdamped

B: Critically damped

A: overdamped

Which would you choose for your shock absorbers?





Homework (HW)

- Note Summary (p.315)
- Discuss some Questions (p.316)
- Choose HW (Problems, starting p.317)

- Get as far as you can on every HW problem on your own after class
- Then start talking with peers, Zita, Quasr
- Help session here next Thursday at 3:00

- HW due before class next Friday
- Only NEAT and STAPLED HW will be accepted

Summary

A vibrating object undergoes **simple harmonic motion** (SHM) if the restoring force is proportional to the displacement,

$$F = -kx. \quad \textbf{(11–1)}$$

The maximum displacement is called the **amplitude**.

The **period**, T, is the time required for one complete cycle (back and forth), and the **frequency**, f, is the number of cycles per second; they are related by

$$f = \frac{1}{T}. \quad \textbf{(11–2)}$$

The period of vibration for a mass m on the end of a spring is given by

$$T = 2\pi\sqrt{\frac{m}{k}}. \quad \textbf{(11–7a)}$$

SHM is **sinusoidal**, which means that the displacement as a function of time follows a sine or cosine curve.

During SHM, the total energy

$$E = \tfrac{1}{2}mv^2 + \tfrac{1}{2}kx^2 \quad \textbf{(11–3)}$$

is continually changing from potential to kinetic and back again.

When friction is present (for all real springs and pendulums), the motion is said to be **damped**. The maximum displacement decreases in time, and the energy is eventually all transformed to thermal energy.

Questions

1. Give some examples of everyday vibrating objects. Which exhibit SHM, at least approximately?
2. Is the acceleration of a simple harmonic oscillator ever zero? If so, where?
3. Explain why the motion of a piston in an automobile engine is approximately simple harmonic.
4. Real springs have mass. Will the true period and frequency be larger or smaller than given by the equations for a mass oscillating on the end of an idealized massless spring? Explain.
5. How could you double the maximum speed of a simple harmonic oscillator (SHO)?
6. A 5.0-kg trout is attached to the hook of a vertical spring scale, and then is released. Describe the scale reading as a function of time.

HW Problems

Look at Ch.11 # 1, 2, 3, 5 together.

Together, choose about 3 problems per section to be due next Friday.

Week 3	Monday 19 Jan.	**due: teams post PIQs** on Tuesday readings on Moodle (finish readings and pre-seminar with your team over the weekend)
Monday is MLK day. Volunteer opportunity: **Musical Instrument Drive.** This is a project to collect, repair and provide musical instruments for underprivileged youth. **Volunteers** are needed to help **repair and restore donated instruments** and teaching youth the basics of the instruments. There will be a brief orientation for volunteers. Donations of instruments are also appreciated! **To volunteer or for more information: mlkinstrumentdrive@gmail.com**		
	Tuesday 20 Jan.	Film in COM 110: Margaret Mead - A Life Possible lecture on performance pieces for tonight
	Inauguration day! Acceptance speech at noon Eastern time (this will be over by the time class starts, so don't miss class)	Seminar Reading * Margaret Mead: *Sex and Temperament* * Margaret Mead: *Cybernetics of Cybernetics* * Mead and Bateson: *Interview* * Gregory Bateson: *The Function of Humor…*
		8 pm concert in Seattle's Benaroya Hall - San Francisco Symphony plays (meet vans at ___) *Aaron Copeland: *Our Town* *Alban Berg: *Three Pieces for Orchestra* *Johannes Brahms: *Symphony #1*
	Thursday 22 Jan.	1-5: Computer music workshop in ACC for Group C
		3-5: Physics help session in CAL for Group P (Ch.11a HW due tomorrow: see Moodle for details)
	Friday 23 Jan.	1-3: Physics of Sound in CAL (Ch.11b:6,7,8,9) for group P **HW 11a due** before class (HW=homework)
		3-5: Continue classes or Seminar 2 on Mead (TBD)