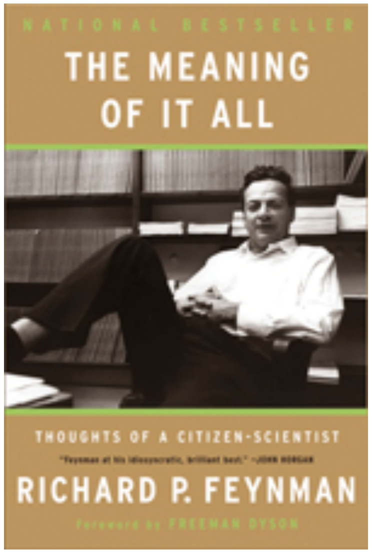
Physics 116

Lecture 10
Review: oscillations and waves
Oct 14, 2011



If we have time to spare:
connection to this year's UW Common Book
Richard Feynman - Nobel laureate in physics

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Announcements

- Exam 1 is Monday!
  - **All multiple choice**, similar to HW problems
    - **YOU must bring a standard mark-sense (bubble) sheet**
  - Closed book/notes, **formula page provided**
  - **You provide: bubble sheet, pencils, calculator*, brain**

  *** laptop, netbook, iPad, or equivalent NOT ALLOWED: NO wifi !**
- Covers material in Chs.13 and 14 (through today's class only)
  - Damped/driven oscillators will NOT be on test
- Please take alternate seats for the exam (empty seat between students) - Latecomers can sit at tables in front or back
- Today = review and "practice exam" = examples similar to exam questions
  - Slides from today will be posted immediately on the website
  - Formula sheet is included in today's slides and also on website
    - you will get a copy of formula page as part of the exam paper

Lecture Schedule

(up to exam 1)

date	*day*	*Session*	*Topic*	*Readings*
9/30/10	Thurs	1	Periodic motion and oscillations	13.1
10/1/10	Fri	2	Simple harmonic motion and circular motion	13.2 –13.4
10/4/10	Mon	3	Mass-spring system, energy conservation in SHM	13.5 –13.6
10/5/10	Tues	4	The pendulum; damped and driven oscillations [HW 1 due]	13.7 –13.8
10/7/10	Thurs	5	Types of waves; waves on a string; harmonic functions	14.1 –14.3
10/8/10	Fri	6	Sound	14.4 –5
10/11/10	Mon	7	Doppler shift; interference	14.6
10/12/10	Tues	8	Superposition	14.7
10/14/10	Thurs	9	Standing Waves & Beats [HW 2 due]	14.8 - 14.9
10/15/10	Fri	10	Review	
10/18/10	Mon	11	EXAM 1 (covers Chs. 13-14)	

Today

The story so far – all the stuff you have learned about in 116:

- Periodic motion (descriptive)
- Simple harmonic motion
    - Restoring force
    - Sine/cosine behavior for x, v, a
    - Uniform circular motion and SHM
    - Mass on a spring as example of SHM
    - Relations between kinetic, potential and total E
    - Pendulum motion
- Waves and wave phenomena
    - Types of waves (transverse, longitudinal, water)
    - Waves on a string
    - Describing waves as harmonic functions of x and t
    - Sound waves
    - Sound intensity and dB
    - Doppler effect
    - Superposition and interference of waves
    - Standing waves: intensity patterns fixed in space
    - Beats: intensity patterns moving in space

Clicker quiz 3

Two pure tones are sounded together and a particular beat frequency is heard.

What happens to the beat frequency if the frequency of the ***HIGHER*** of the two frequencies is increased?

A) It increases.

B) It decreases.

C) It does not change.

D) It becomes zero.

NY Times, 10/14/11:

…students exchanged exam horror stories… "I know a girl who saw the physics paper and she fainted," said Nikita Sachdeva, her eyes widening.

Don't faint!
Our exam will not be so scary.

Formula page

$$2\pi\left(\frac{1}{T}\right)=2\pi f$$

$$\omega=2\pi f$$

$$\theta(t)=\omega t$$

$$x(t)=A\cos\left(2\pi\left(\frac{t}{T}\right)\right)=A\cos(\omega t)$$

$$x(t)=A\cos(\omega t)$$

$$v(t)=-A\omega\sin(\omega t)$$

$$a(t)=-A\omega^2\cos(\omega t)$$

$$F_{SHM}=-kx$$

$$\omega_{SHM}=\sqrt{\frac{k}{m}}$$

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

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

$$K=\frac{1}{2}mv^2=\frac{1}{2}kA^2\left(\sin(\omega t)\right)^2$$

$$E=U+K=\frac{1}{2}kA^2$$

$$\sin\theta\approx\theta \rightarrow mg\sin\theta\approx mg\theta$$

$$F_{restoring}=-mg\theta=-\left(\frac{mg}{L}\right)s$$

$$s=L\theta$$

(displacement s = arc on circle of radius R)

$$k=\left(\frac{mg}{L}\right)$$

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

$$y=A\cos\left(\frac{2\pi}{\lambda}x-\frac{2\pi}{T}t\right)$$

$$\beta[dB]=10\log_{10}\left(\frac{I}{I_0}\right) \quad I_0=\text{reference level}$$

$$I_0=10^{-12}\,\text{W/m}^2=10^{-16}\,\text{W/cm}^2$$

$$I_{Pain}=10^{13}I_0$$

$$f'=f\left(1+\frac{u_{OBS}}{c}\right) \quad \text{(stationary source)}$$

$$f'=f\left(\frac{1}{1-u_{SRC}/c}\right) \quad \text{(stationary observer)}$$

$$f'=f\frac{\left(1\pm\frac{u_{OBS}}{c}\right)}{\left(1\mp\frac{u_{SRC}}{c}\right)}$$

(source and/or obs moving)
(upper sign=approaching, lower sign =separating)

waves on a string, or open pipe:

$$\lambda_1=2L_1 \rightarrow L_1=\frac{\lambda_1}{2} \rightarrow f_1=\frac{v}{\lambda_1}=\frac{v}{2L_1}$$

waves in a pipe with one end closed:

$$\lambda_1=4L_1 \rightarrow L_1=\frac{\lambda_1}{4} \rightarrow f_1=\frac{v}{\lambda_1}=\frac{v}{4L_1}$$

n th harmonic:

$$\lambda_n=\frac{\lambda_1}{n}, \quad L_n=\frac{L_1}{n}, \quad f_n=\frac{v}{\lambda_n}=n\,f_1$$

$$y_1(t)=A\cos(2\pi f_1 t), \quad y_2(t)=A\cos(2\pi f_2 t)$$

$$y_1+y_2=2A\cos\left(2\pi\left[\frac{f_1-f_2}{2}\right]t\right)\cos\left(2\pi\left[\frac{f_1+f_2}{2}\right]t\right)$$

$$f_{BEAT}=|f_1-f_2| \quad f_{OSC}=\frac{f_1+f_2}{2}$$

1. A sewing machine needle moves up and down in simple harmonic motion with an amplitude of 1.27 cm and a frequency of 2.55 Hz.

(a) What is the maximum speed of the needle?

(b) What is the maximum acceleration of the needle?

$$x(t) = A\cos\left(2\pi f\ t\right) = 1.27cm\cos\left(2\pi\left[2.55Hz\right]t\right)$$

$$v(t) = -A\omega\sin\left(\omega t\right) \rightarrow v_{\max} = A\omega = \left(1.27cm\right)2\pi\left(2.55Hz\right) = 20.3cm/s$$

$$a(t) = -A\omega^2\cos\left(\omega t\right) \rightarrow a_{\max} = A\omega^2 = \left(1.27cm\right)\left(2\pi\cdot 2.55Hz\right)^2 = 326cm/s^2$$

Note: I've fixed typos in these slides, so compare to your class notes.
(and many thanks to students who found some I'd missed!)
-- JW, 10/14

2. A mass is oscillating on a spring with a period of 4.60 s. At t = 0 s the mass has zero speed and is at x = 8.30 cm. What is its speed at t = 2.50 s?

A) 10.9 cm/s
B) 3.06 cm/s
C) 3.32 cm/s
D) 1.80 cm/s
E) 0 cm/s

$$x(t) = A\cos\left(2\pi\left(\frac{t}{T}\right)\right)$$

$$x(0) = A = 8.3cm$$

$$v(t) = -A\omega\sin(\omega t)$$

$$\omega = \left(\frac{2\pi}{T}\right)$$

$$v(2.5\,\text{sec}) = -8.3cm\left(\frac{6.28}{4.6s}\right)\sin\left(2\pi\left(\frac{2.5s}{4.6s}\right)\right)$$

$$= (-8.3cm)(1.365\ rad/s)(-0.2697)$$

$$= 3.06cm$$

Answer: B

3. If the frequency of the motion of a simple harmonic oscillator is doubled, by what factor does the maximum acceleration of the oscillator change?

A) 2
B) 4
C) 1
D) 1/2
E) 1/4

$$a(t) = -A\omega^2 \cos\left(\omega t\right)$$

$$\omega_{SHM} = 2\pi f_{SHM} \rightarrow a(t) \propto \omega_{SHM}^2 \propto f_{SHM}^2$$

$$f \rightarrow 2f \Rightarrow a \rightarrow 4a$$

Answer: B

4. A mass of 1.53 kg is attached to a spring and the system is undergoing simple harmonic oscillations with a frequency of 1.95 Hz and an amplitude of 7.50 cm. What is the speed of the mass when it is 3.00 cm from its equilibrium position?

A) 0.0368 m/s

B) 0.551 m/s

C) 0.421 m/s

D) 0.842 m/s

E) 0.919 m/s

$$x(t) = A\cos(\omega t)$$

$$A = 7.5cm, \quad \omega = 2\pi[1.95Hz] = 12.25rad/s$$

$$3cm = 7.5cm\left(\cos\left(2\pi[1.95Hz]t\right)\right)$$

$$\frac{3}{7.5} = \cos\left([12.25rad/s]t\right)$$

$$\cos^{-1}\left(\frac{3}{7.5}\right) = [12.25rad/s]t$$

$$t = \frac{\cos^{-1}(0.4)}{[12.25rad/s]} = \frac{1.159rad}{12.25rad/s} = 0.095s$$

$$v(t) = -A\omega\sin(\omega t)$$

$$= -7.5cm[12.25rad/s]\sin\left([12.25rad/s]0.095s\right)$$

$$= -7.5cm[12.25rad/s]0.9165 = 84.2cm/s$$

Answer: D

5. On the Moon, the acceleration of gravity is g/6. If a pendulum has a period T on Earth, what will its period be on the Moon?

A) $\sqrt{6}T$

B) $T / \sqrt{6}$

C) T/6

D) 6T

E) T/3

$$T_{\oplus} = 2\pi\sqrt{\frac{L}{g}} \rightarrow T_{moon} = 2\pi\sqrt{\frac{L}{g/6}} = \sqrt{6}T_{\oplus}$$

Answer: A

6. An earthquake generates three kinds of waves: surface waves (L-waves), which are the slowest and weakest, shear (S) waves, which are transverse waves and carry most of the energy, and pressure (P) waves, which are longitudinal waves and are the fastest.

The speed of P waves is approximately 7 km/s, and that of S waves is about 4 km/s. People do not generally feel the P waves, but animals seem to be sensitive to them.

If a person reports that her dog started barking 20 seconds "before the earthquake," then approximately how far was the origin of the earthquake?

A) 100 km
B) 200 km
C) 300 km
D) 400 km
E) 500 km

$$x = c\,t \quad \rightarrow \quad x = c_P t_p = c_S t_S$$

$$t_P = \frac{c_S}{c_P} t_S \quad \rightarrow \quad t_p - t_S = t_S\left(\frac{c_S}{c_P} - 1\right)$$

$$\left|t_p - t_S\right| = 20\,\text{sec} = t_S\left|\left(\frac{4km/s}{7km/s} - 1\right)\right| = t_S(0.43)$$

$$20\,\text{sec} = t_S(0.43) \quad \rightarrow \quad t_S = 47s \;\; = \text{travel time for S-wave}$$

$$x = c_S t_S = (4km/s)47s = 186km = \text{travel distance for S-wave}$$

Answer: B

7. The sound of 40 decibels is

A) twice as intense as the sound of 20 decibels.

B) four times as intense as the sound of 20 decibels.

C) 10 times as intense as the sound of 20 decibels.

D) 100 times as intense as the sound of 20 decibels.

E) 1000 times as intense as the sound of 20 decibels.

$$\beta[dB]] = 10\log_{10}\left(\frac{I}{I_0}\right) \quad I_0 = \text{reference} \quad \text{level}$$

$$40dB = 10\log_{10}\left(\frac{I_{40dB}}{I_0}\right) \qquad 20dB = 10\log_{10}\left(\frac{I_{20dB}}{I_0}\right)$$

$$\text{take antilogs: } \log_{10}^{-1}\left(\frac{40}{10}\right) = 10^4 = \left(\frac{I_{40dB}}{I_0}\right)$$

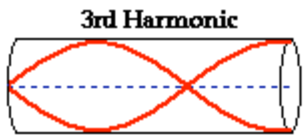
$$\log_{10}^{-1}\left(\frac{20}{10}\right) = 10^2 = \left(\frac{I_{20dB}}{I_0}\right)$$

Answer: D

$$\frac{I_{40dB}}{I_{20dB}} = \frac{10^4}{10^2} = 10^2$$

8. In a resonating pipe which is open at one end and closed at the other, there

A) are displacement nodes at each end.
B) are displacement antinodes at each end.
C) is a displacement node at the open end and a displacement antinode at the closed end.
D) is a displacement node at the closed end and a displacement antinode at the open end.



Answer: D

9. As you stand by the side of the road, a car approaches you at a constant speed, sounding its horn, and you hear a frequency of 76 Hz. After the car goes by, you hear a frequency of 65 Hz. What is the speed of the car? The speed of sound in air is 343 m/s.

A) 26 m/s
B) 27 m/s
C) 28 m/s
D) 29 m/s
E) 30 m/s

$$f' = f\left(\frac{1}{1 \mp u_{SRC}/c}\right) \quad \text{(stationary observer)}$$

$$76Hz = f\left(\frac{1}{1 - u_{SRC}/c}\right) \quad \text{(car approaching)}$$

$$65Hz = f\left(\frac{1}{1 + u_{SRC}/c}\right) \quad \text{(car moving away)}$$

$$f = 76Hz\left(1 - u_{SRC}/c\right) = 65Hz\left(1 + u_{SRC}/c\right)$$

$$76Hz - (76Hz)(u_{SRC}/343m/s) = 65Hz + (65Hz)(u_{SRC}/343m/s)$$

$$(76Hz - 65Hz)343m/s = (76Hz + 65Hz)u_{SRC}$$

$$\frac{(76Hz - 65Hz)}{(76Hz + 65Hz)}343m/s = u_{SRC} = 26.8m/s$$

Answer: B

10. A policeman in a stationary car measures the speed of approaching cars by means of an ultrasonic device that emits a sound with a frequency of 39.6 kHz. A car is approaching him at a speed of 35.0 m/s. The wave is reflected by the car and interferes with the emitted sound producing beats. What is the frequency of the beats? The speed of sound in air is 343 m/s.

A) 5000 Hz
B) 4500 Hz
C) 8490 Hz
D) 9000 Hz
E) 4250 Hz

Reflected wave will have f ‘ = frequency observed by car.
So f ’ = frequency for stationary source and moving observer.
but f’ in car’s reference frame is heard as f’’ in stationary frame,
where f’’ = frequency for stationary observer and moving source
(car acts as moving source of f’)

$$f' = f\left(1 + \frac{u_{OBS}}{c}\right) \quad \text{(observed freq for stationary source, moving observer)}$$

$$f' = 39.6kHz\left(1 + \frac{35m/s}{343m/s}\right) \quad (= \text{reflected-wave frequency})$$

$$f' = 39.6kHz(1.102) = 43.6kHz$$

$$f'' = f'\frac{1}{\left(1 - \frac{u_{OBS}}{c}\right)} \quad (\text{stationary observer, moving source with } f'\ )$$

$$f'' = 43.6kHz\frac{1}{\left(1 - \frac{35m/s}{343m/s}\right)} \quad (\text{reflected-wave frequency in } \textit{stationary observer's} \text{ frame})$$

$$f'' = 43.6kHz(1.114) = 48.6kHz$$

$$f_{BEAT} = |f - f''| = |39.6kHz - 48.6kHz| = 9kHz$$

Answer: D

See you Monday!

Please take alternate seats for the exam (empty seat between students)
Latecomers can sit at tables in front or back

If we have time to spare:

connection to this year's UW Common Book
Richard Feynman - Nobel laureate in physics, famous 1964 lecture series at Cornell U. - more samples will be played later

http://www.youtube.com/watch?v=1SrHzSGn-I8&feature=related

http://www.washington.edu/news/articles/much-more-than-physics-remembering-common-book-author-richard-feynman