Phys 111: Lecture 30

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The 30th Day: “Exam 3 Review”

Today’s Topics

1. Simple Harmonic Motion
2. Pressure & Fluids
3. Temperature & Heat
4. Waves

Reading Graphs for Simple Harmonic Motion

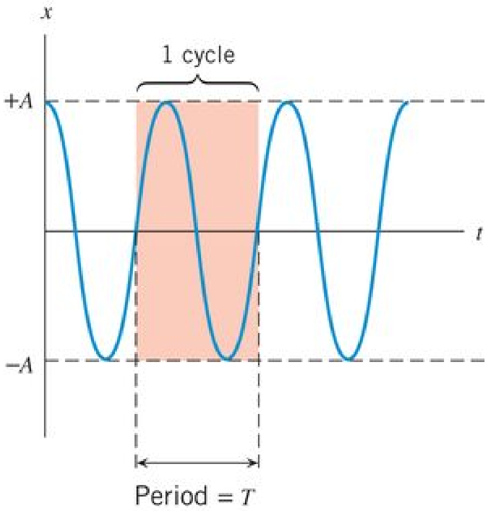

Figure: 22.3 Example graph for simple harmonic motion

Simple Harmonic Motion Equations

The following equations can be used for modeling any simple harmonic motion that begins with max amplitude:

$$\theta = \omega t \qquad \omega = 2\pi f \qquad f = \frac{1}{T}$$

$$\omega_{sp} = \sqrt{\frac{k}{m}} \qquad \omega_{pen} = \sqrt{\frac{g}{L}}$$

$$x = Acos(\omega t), \qquad x_{max} = A$$

$$v_x = -A\omega sin(\omega t), \quad v_{max} = A\omega$$

$$a_x = -A\omega^2 cos(\omega t), \quad a_{max} = A\omega^2$$

Exercise #1

C&J 10.15 When responding to sound, the human eardrum vibrates about its equilibrium position. Suppose an eardrum is vibrating with an amplitude of $6.3 \times 10^{-7}\ m$ and a maximum speed of $2.9 \times 10^{-3}\ m/s$.

a. What is the frequency (in Hz) of the eardrum's vibration?
b. What is the maximum acceleration of the eardrum?

Exercise #1 Answer

C&J 10.15 Consider SHM with an amplitude of $6.3 \times 10^{-7}\ m$ and a maximum speed of $2.9 \times 10^{-3}\ m/s$. The following answers were calculated using the relationships

$$v_{max} = A\omega,$$

$$a_{max} = A\omega^2,\ and$$

$$\omega = 2\pi f$$

a. What is the frequency (in Hz) of the eardrum's vibration?

$$f = 733\ Hz$$

b. What is the maximum acceleration of the eardrum?

$$a_{max} = 13.3\ m/s^2$$

Summary of Pressure & Fluids

For the simplest motions of flowing fluids:

- Pressure definition: $P = F_{\perp}/A$
- Hydrostatic Pressure: $P_2 = P_1 + \rho g h$
- Buoyancy Force: $F_b = \rho g V$
- Continuity of Mass Flow: $(\rho A v)_{in} = (\rho A v)_{out}$
- Ideal fluids are incompressible and non-viscous
- Real fluids are compressible and viscous, but some are close to ideal

Exercise #2

C&J 11.20 The Mariana trench is located in the floor of the Pacific Ocean at a depth of about $11,000\ m$ below the surface of the water. The density of seawater is $1,025\ kg/m^3$.

a. If an underwater vehicle were to explore such a depth, what force would the water exert on the vehicle's observation window (radius $= 0.10\ m$)?
b. For comparison, determine the weight of a jetliner whose mass is $1.2 \times 10^5\ kg$.

Exercise #2 Answer

C&J 10.15 Consider the pressure levels at a depth of $11,000\ m$ below the surface of the ocean. The density of seawater is $1,025\ kg/m^3$.

Using $P_h = P_{atm} + \rho g h$ and $P = F_{\perp}/A$ we can determine:

a. The force on a circular area with a radius of $0.10\ m$ would be

$$3.6 \times 10^6\ N$$

b. For comparison, the weight of a jetliner whose mass is $1.2 \times 10^5\ kg$ would be

$$1.2 \times 10^6\ N.$$

Exercise #3 (In Class)

C&J 11.56 Use conservation of mass (continuity) to answer the following:

a. The volume flow rate in an artery supplying the brain is $3.6 \times 10^{-6}\ m^3/s$. If the radius of the artery is $5.2\ mm$, determine the average blood speed.

b. Find the average blood speed at a constriction in the artery if the constriction reduces the radius by a factor of 3. Assume that the volume flow rate is the same as that in part 56(a).

Exercise #3 Start

C&J 11.56 Let's revisit the definition of volume flow rate Q for part (a) and then relate the two radii to get a new average speed:

$$Q = Av_{ave} = (\pi r^2)v_{ave}$$

$$v = \frac{Q}{\pi r^2}$$

Exercise #3 Answers

C&J 10.56 The strategy is to calculate one velocity and then use the differences in radii to calculate the second velocity very quickly.

Since $r_2 = r_1/3$, then $A_2 = A_1/9$. Using

$$v_{ave} = \frac{Q}{A}$$

a. $v_1 = 4.24\ cm/s$

b. $v_2 = 9v_1 = 38.2\ cm/s$

Temperature Equations

Know how to use the following:

- $T_K = T_C + 273.15$
- $T_C = \left(\frac{5}{9}\right)\left(T_F - 32.0\right)$
- $\Delta L = \alpha L_o \Delta T$
- $Q = mc\Delta T$
- $Q_L = mL$

Exercise #4 (In-Class)

C&J 12.5 Dermatologists often remove small precancerous skin lesions by freezing them quickly with liquid nitrogen, which has a temperature of $77\ K$. What is this temperature on the

a. Celsius and

b. Fahrenheit scales?

Exercise #4 Translation

C&J 12.5 Determine how to report a temperature of $T = 77\ K$ in $^\circ C$ and $^\circ F$.

Strategy: Use the conversions for temperatures, meaning the equations for finding temperatures in different scales.

$$T_K = T_C + 273.15$$

$$T_F = \left(\frac{9}{5}\right) T_C + 32.0$$

Exercise #4 Answer

C&J 12.5 A temperature of $T = 77\ K$ is equal to

a. $T = -196^{\circ}C$ and

b. $T = -321^{\circ}F$

Exercise #5 (In-Class)

C&J 12.10 A steel section of the Alaskan pipeline had a length of $65\ m$ and a temperature of $18^{\circ}C$ when it was installed. What is its percent change in length when the temperature drops to a frigid $-45^{\circ}C$?

We need to know the linear coefficient for steel: $\alpha = 12 \times 10^{-6}\ (^{\circ}C)^{-1}$.

Exercise #5 Answers

C&J 12.10 The linear coefficient for steel is $\alpha = 12 \times 10^{-6}\ (^{\circ}C)^{-1}$, the original length was measured to be $L_o = 65\ m$, and the temperature change was measured to be $\Delta T = -63^{\circ}C$. What is the percent change in length for such a temperature change?

We need to use the reported values with the relationship

$$\Delta L = \alpha L_o \Delta T$$

$$\frac{\Delta L}{L_o} = \alpha \Delta T = -7.56 \times 10^{-4}$$

$$\%\Delta L = \left(\frac{\Delta L}{L_o}\right) \times 100\% = (\alpha \Delta T) \times 100\% = -0.756\%$$

Exercise #6 (In-Class)

C&J 12.57 How much heat must be added to $0.45\ kg$ of aluminum to change it from a solid at $130°C$ to a liquid at $660°C$ (its melting point)? The latent heat of fusion for aluminum is $4.0 \times 10^5\ J/kg$ and the specific heat capacity of aluminum is $9.00 \times 10^2\ J/(°C \cdot kg)$.

Exercise #6 Translation

Calculate the total heat required to melt aluminum by calculating the heat for two distinct processes:

1. heating the solid to the melting point
2. melting all of the aluminum sample.

$$Q_{tot} = Q_1 + Q_2$$

$$Q_{tot} = mc\Delta T_1 + mL$$

Exercise #6 Answers

C&J 12.57 How much heat must be added to $0.45\ kg$ of aluminum to change it from a solid at $130°C$ to a liquid at $660°C$ (its melting point)? The latent heat of fusion for aluminum is $4.0 \times 10^5\ J/kg$ and the specific heat capacity of aluminum is $9.00 \times 10^2\ J/(°C \cdot kg)$.

$$Q_{tot} = mc\Delta T_1 + mL$$

$$Q_1 = mc\Delta T$$

$$Q_2 = mL$$

$$Q_1 \approx 215\ kJ$$

$$Q_2 \approx 180\ kJ$$

Wave Basics

For waves, including light and sound:

- $v_w = f\lambda$
- $v_w = \lambda / T$
- $c = 3.00 \times 10^8 \ m/s$
- $v_{snd} \approx 345 \ m/s$ (in air)
- $v_{st} = \sqrt{\frac{F}{m/L}}$

Exercise #7

C&J 16.1 Light is an electromagnetic wave and travels at a speed of $3.00 \times 10^8\ m/s$. The human eye is most sensitive to yellow-green light, which has a wavelength of $5.45 \times 10^{-7}\ m$. What is the frequency of this light?

Exercise #7 Translation

C&J 16.1 Calculate the frequency of yellow-green light in vacuum that travels at the speed of light $c = 3.00 \times 10^8\ m/s$ with a wavelength of $\lambda = 5.45 \times 10^{-7}\ m$.

Need to know that wave speed is

$$v_w = f\lambda$$

Exercise #7 Answer

C&J 16.1 $c = 3.00 \times 10^8\ m/s$, $\lambda = 5.45 \times 10^{-7}\ m$

$$v_w = f\lambda$$

$$f = \frac{v_w}{\lambda}$$

$$f = \left(\frac{3.0 \times 10^8\ m/s}{5.45 \times 10^{-7}\ m}\right)$$

$$f = 5.50 \times 10^5\ GHz$$

Exercise #8 (In-Class)

C&J 16.13 The middle C string on a piano is under a tension of $944\ N$. The period and wavelength of a wave on this string are $3.82\ ms$ and $1.26\ m$, respectively. Find the linear density of the string.

Exercise #8 Translation

C&J 16.13 Calculate m/L for a middle C string under a tension of $F = 944\ N$. For this string $T = 3.82\ ms$ and $\lambda = 1.26\ m$.

$$v_{st} = \sqrt{\frac{F}{m/L}}$$

Remember that

$$v_w = f\lambda = \frac{\lambda}{T}$$

Exercise #8 Work

C&J 16.13 Calculate m/L for a middle C string under a tension of $F = 944\ N$. For this string $T = 3.82\ ms$ and $\lambda = 1.26\ m$.

$$\frac{\lambda}{T} = \sqrt{\frac{F}{m/L}}$$

$$\left(\frac{\lambda}{T}\right)^2 = \frac{F}{m/L}$$

$$\frac{m/L}{F} = \left(\frac{T}{\lambda}\right)^2$$

$$m/L = F\left(\frac{T}{\lambda}\right)^2$$

Exercise 8 Answer

C&J 16.13 Calculate m/L for a middle C string under a tension of $F = 944\ N$. For this string $T = 3.82\ ms$ and $\lambda = 1.26\ m$.

$$m/L = F\left(\frac{T}{\lambda}\right)^2$$

$$m/L = (944\ N)\left(\frac{3.82 \times 10^{-3}\ s}{1.26\ m}\right)^2$$

$$m/L = 8.68\ g/m$$

$$m/L = 8.68\ kg/km$$

Wave Basics Continued

For waves.

- $I = P/A$
- $I_o = 1.00 \times 10^{-12}\ W/m^2$ (sound only)
- $\beta = (10\ dB) log(I/I_o)$
- $I = I_o 10^b$
- $b = \beta/10\ dB$
- $f_b = |f_2 - f_1|$

Exercise # 9

C&J 16.54 A source of sound is located at the center of two concentric spheres, parts of which are shown in the drawing. The source emits sound uniformly in all directions. On the spheres are drawn three small patches that may or may not have equal areas. However, the same sound power passes through each patch. The source produces $2.3\,W$ of sound power, and the radii of the concentric spheres are $r_A = 0.60\,m$ and $r_B = 0.80\,m$.

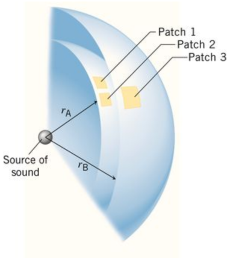

Figure: 28.3 Spherically generated sound[3]

[3] C&J Figure 16.P54

Exercise # 9 Questions

C&J 16.54 The source produces $2.3\ W$ of sound power, and the radii of the concentric spheres are $r_A = 0.60\ m$ and $r_B = 0.80\ m$.

a. Determine the sound intensity at each of the three patches.
b. The sound power that passes through each of the patches is $1.8 \times 10^{-3}\ W$. Find the area of each patch.

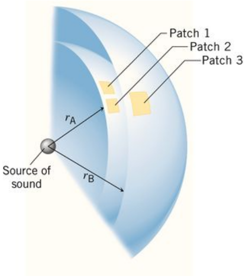

Figure: 28.3 Spherically generated sound[3]

[3] C&J Figure 16.P54

Exercise #9(a) Answer

C&J 16.54(a) Use the relationship for intensity to calculate three intensities.

Data: $P = 2.3\ W$, $r_A = 0.60\ m$, and $r_B = 0.80\ m$.

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

$$I_1 = I_2 = \frac{2.3\ W}{4\pi(0.60\ m)^2} = 0.51\ \frac{W}{m^2}$$

$$I_3 = \frac{2.3\ W}{4\pi(0.80\ m)^2} = 0.29\ \frac{W}{m^2}$$

C&J 17.21 A $440.0\ Hz$ tuning fork is sounded together with an out-of-tune guitar string, and a beat frequency of $3\ Hz$ is heard. When the string is tightened, the frequency at which it vibrates increases, and the beat frequency is heard to decrease. What was the original frequency of the guitar string?

Exercise #10 Work

C&J 17.21 A $440.0\ Hz$ tuning fork is sounded together with an out-of-tune guitar string, and a beat frequency of $3\ Hz$ is heard.

When the frequency of the guitar increases and the beat frequency decreases that must mean that the string's frequency was $3\ Hz$ less than the frequency of the tuning fork, not higher.

$$f_o = 437.0\ Hz$$