1 **DIMENSIONS OF THE SINE WAVE**

- dimensions of sine waves
  - Amplitude
  - Phase
  - Frequency/Period: f = 1 / T or T = 1 / f

Note: when a sine wave represents something in space, wavelength is used instead of period.

2 **Units of Measure For Frequency and Period**

- Frequency (f)
  - Hz to kHz: Divide by 1,000
  - kHz to Hz: Multiply by 1,000
- Period (T)
  - s to ms: Multiply by 1,000
  - ms to s: Divide by 1,000
- f = 1/ T and T = 1/ f

3 **Important Phasic Relations**

- Displacement (Elasticity)
- Velocity (Momentum; Damping)
- Acceleration
- Relations:
  - c leads x by 90^{o}
  - a leads c by 90^{o},

    and
  - a leads x by 180^{o}

4 **DIMENSIONS OF THE SINE WAVE**

- (5) WAVELENGTH (λ)
- Two quantities are measured with respect to time
  - Frequency (f)
  - Speed of sound (s)

5 **Wavelength**

- Wavelength (λ) relates frequency and speed of sound
- λ = distance traveled during one period
- $\lambda = s / f$
- Examples
  - In air: f = 1100 Hz, s = 340 m / s; λ = ?
    - ☑ $\lambda = 340 / 1100 = .3$ m
  - In air: f = 550 Hz, s = 340 m / s; λ = ?
    - ☑ $\lambda = 340 / 550 = .6$ m

6 **DAMPING/ Effects of Friction on Vibratory Motion**

- Oscillating systems encounter opposition to motion: friction, or frictional resistance
- Friction limits velocity
- Amplitude of vibration diminishes over time
- Vibrations are damped

7 **The Magnitude of Damping**

- In Figure,
  - Panel A: lossless system
  - Panel B: low-damped system
  - Panel C: high-damped system

8 ## ACOUSTIC IMPEDANCE

- System engages in SHM: it vibrates freely at its natural frequency (f_{nat})
- $f_{nat} = \sqrt{s/m}$
- What are the concepts involved in this oscillation?
  - ☑ elasticity / restoring force (spring)
  - ☑ inertia / momentum (mass)
  - ☑ friction / damping

9 ## ACOUSTIC IMPEDANCE

- Forces exist that oppose, or impede, motion: Impedance (Z)
- Total impedance has two components:
  - resistance R (friction)
  - reactance X
    - > mass reactance X_m (mass)
    - > compliant reactance X_c (spring)

10 ## Impedance

Resistance (R) Reactance (X)

1
- Friction, or frictional resistance, occurs: kinetic energy is transformed to thermal energy
- Resistance measured in ohms (Ω)
- Resistance is independent of frequency!

2
- Forces that oppose motion in a frequency selective way: frequency dependent
- With X, energy is stored
- With R, energy is dissipated from motion

11 ## Two Components of Impedance

- 1. Energy-dissipating: What is it?
  - ☑ Resistance (R), which is independent of frequency
- 2. Energy-storage: What is it?
  - ☑ Reactance (X), which is dependent on frequency
- Impedance: Complex sum of R & X

12 ## Crucial Phasic Relations

- Opposition to motion from Resistance is in phase with velocity
  - Resistance: in phase with c, M, and damping
- Opposition to motion from Compliance is in phase with elasticity; lags Resistance by 90^o
  - Compliance: in phase with E and x
- Opposition to motion from Mass is in phase with acceleration;

- ♦ leads resistance by 90^o

13 **Two Components of X:**

X_m and X_c

- When one reactance component stores energy, the other gives up energy
- They are 180^o out of phase with one another
- They act in opposition to one another

14 **Mass Reactance: X_m**

- X_m is directly proportional to frequency
- At low frequencies,
  - ♦ X_m negligible; larger amplitude of vibration
- At high frequencies,
  - ♦ X_m large; smaller amplitude of vibration
- X_m

f

15 **Compliant Reactance: X_c**

- At low frequencies,
  - ♦ X_c large; smaller amplitude of vibration
- At high frequencies,
  - ♦ X_c negligible; larger amplitude of vibration
- X_c is inversely proportional to frequency
- X_c

f

16 **Mass Reactance (X_m) and Compliant Reactance (X_c)**

- What if $X_m = X_c$?
  - ♦ If $X_m = X_c$, X = 0
  - ♦ Z = R
  - ♦ Impedance is minimal
  - ♦ Amplitude of vibration is largest
  - ♦ f_{nat}

17 **Impedance (Z)**

(What to remember)

- R causes energy to be dissipated
  ie. resistance from friction)
- X causes energy to be stored
  - ♦ X_m leads R by 90^o
    ie. Reactance from mass
  - ♦ X_c lags R by 90^o
    ie. Reactance from compliance (spring)
  - ♦ X_m leads X_c by 180^o