Physics in Entertainment and the Arts

Chapter V

Simple Harmonic Motion and Pure Tone Sounds

- The actual sounds made by most things
  - have multiple frequencies (wavelengths)
mixed together

Pure Tone Sounds

- Pure tone sounds on the other hand
  - are single frequency (wavelength) waves

Simple Harmonic Motion

- If we take a small weight and suspend it from a spring
  - the spring will stretch to accommodate the weight

  - For small amounts of weight, this stretch is proportional to the weight

Simple Harmonic Motion

- In mathematical terms:
  \[ \text{Force} = k \times \text{Stretch} \]

  - where \( k \) is a constant of proportionality called the “spring constant”

  - This equation is known as Hooke’s Law

Hooke’s Law

Linear relationship: \( F = k x \)

From Tippens: Shifting, 7th Ed. McGraw Hill
Hooke’s Law

- Hooke’s Law only works until you overstretch the spring.
- The spring then becomes permanently deformed!
- Note: Newtons (N) are the metric system unit for force (weight)
  - the English unit is the pound (lb)
  - 1 lb ~ 4.5 N

Simple Harmonic Motion

- If we now pull down on the weight and then release it
  - the weight will bob up and down in a motion called “simple harmonic motion”
  - SHM is oscillatory (repeatable) in nature
  - and therefore has a defined frequency and period
  - The weight oscillates about its equilibrium position

Simple Harmonic Motion

- If we attach a pen to the weight and let it draw on a strip of paper moving at a constant speed
  - it will trace out the signature SHM plot
  - This plot is called a “sinusoid”

Other ways to produce SHM

- A rotating ball
- A swinging ball (called a “pendulum”)

Simple Harmonic Motion

- So we see that an object in SHM produces a wave that is graphically equivalent to a pure tone
- Or conversely...
  - A pure tone sound can be produced by an object undergoing SHM
Simple Harmonic Motion
Examples

• Plucking a string – approximately SHM
  – piano, guitar, harp

• Vibrating a reed – approximately SHM
  – clarinet, oboe, saxophone

• Vibrating a person’s lips – approx SHM
  – trumpet, trombone, French horn