

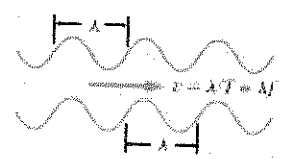
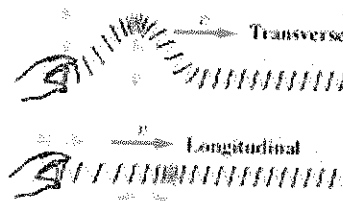
CHAPTER II SUMMARY

Wave Properties

(Section 11.1) A **wave** is a traveling disturbance that carries energy but not matter. In a **transverse wave**, the disturbance is perpendicular to the direction of wave travel. In a **longitudinal wave**, the disturbance consists of a density variation in the direction of travel.

Periodic waves consist of repeated, identical disturbances. **Wave speed, wavelength, and frequency** are fundamentally related.

Speed of a periodic wave: Speed = wavelength \times frequency, or $v = \lambda f$



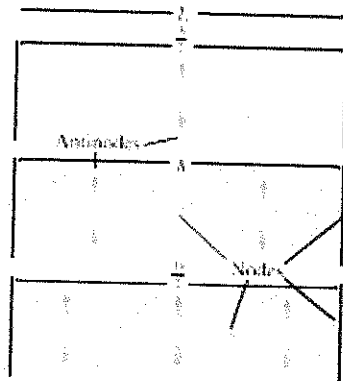
Interference and Standing Waves

(Section 11.2) **Wave interference** occurs when two or more waves meet. Interfering waves follow the **superposition principle**: the total disturbance is the sum of the individual disturbances. **Constructive interference** increases overall wave amplitude; **destructive interference** reduces it. **Standing waves** result from interference of waves reflecting on confined structures.

Wavelength of standing waves on a string fixed at both ends:

$$\lambda = \frac{2L}{n} \quad (n = \text{integer}) \quad f = n \frac{v}{2L}$$

Wave speed on a string: $v = \sqrt{\frac{T}{\mu}}$

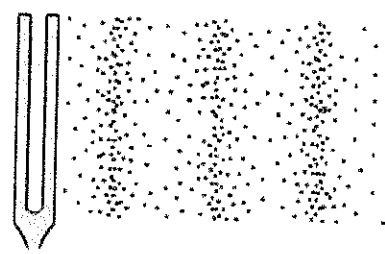


Sound Waves

(Section 11.3) Sound waves are longitudinal waves in air and other media. Most people hear sound with frequencies between 20 Hz and 20 kHz. Frequencies above 20 kHz are called **ultrasonic**; those below 20 Hz are called **subsonic** or **infrasonic**. The frequency of a sound wave is often referred to as its **pitch**.

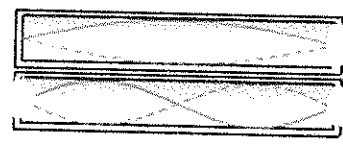
Sound intensity is power per unit area: $I = \frac{P}{A}$

Sound intensity level β = $10 \log\left(\frac{I}{I_0}\right)$ (measured in decibels, dB)



Musical Instruments and Harmony

(Section 11.4) Whole-number ratios of sound frequencies lead to musical harmonics. The 2:1 frequency interval is an **octave**, containing the seven major notes. The size and shape of a musical instrument affect its pitch by determining how and where standing waves form, and the mix of harmonics determines the instrument's unique sound.



$$\lambda = \frac{2L}{n} \quad f = n \frac{v}{2L}$$

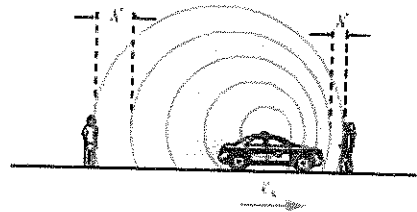
$$\lambda = \frac{4L}{n} \quad f = n \frac{v}{4L}$$

The Doppler Effect

(Section 11.5) The **Doppler effect** is a shift in the frequency of a wave resulting from the relative motion of source and observer. When the two approach, frequency increases. When they recede, frequency decreases.

Source approaching: $f' = \frac{f}{1 - v_s/v}$

Source receding: $f' = \frac{f}{1 + v_s/v}$



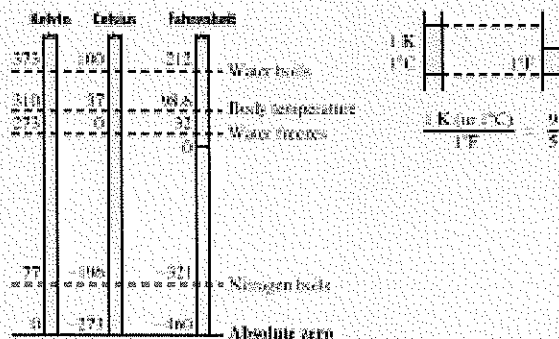
CHAPTER 12 SUMMARY

Temperature and Thermometers

(Section 12.1) **Thermal energy** is the energy of random molecular motion. **Temperature** is a measure of thermal energy. SI temperature measurements use the **Kelvin scale**, with its zero at absolute zero. The **Fahrenheit temperature scale** ($^{\circ}\text{F}$) is common in the United States, while scientists regularly use the **Celsius scale** ($^{\circ}\text{C}$). Thermometers use thermal expansion or changes in electrical properties to measure temperature.

Fahrenheit to Celsius conversion: $T \text{ in } ^{\circ}\text{C} = \frac{5}{9}(T \text{ in } ^{\circ}\text{F} - 32^{\circ})$

Celsius to kelvin conversion: $T \text{ in K} = T \text{ in } ^{\circ}\text{C} + 273.15$



Thermal Expansion

(Section 12.2) Most solids and liquids undergo **thermal expansion** that's proportional to their temperature change. Lengthwise expansion is **linear thermal expansion**, while **volume thermal expansion** occurs when solids expand in every direction and liquids expand as permitted by their containers. Each material has its own **coefficient of thermal expansion**.

Water exhibits unusual behavior, decreasing in volume from its 0°C freezing point until it reaches maximum density at 4°C .

Linear thermal expansion: $\frac{\Delta L}{L} = \alpha \Delta T$, where α is the coefficient of linear expansion.

Volume thermal expansion: $\frac{\Delta V}{V} = \beta \Delta T$, where β is the coefficient of volume expansion.



Ideal Gases

(Section 12.3) **Ideal gases** are so dilute that intermolecular forces are negligible. The pressure of an ideal gas results from collisions between gas molecules and container walls.

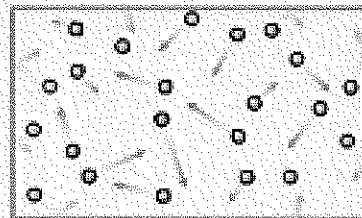
The **ideal-gas law** relates the state variables pressure, volume, temperature, and amount of a gas. The latter is described by the number of molecules N , or the number of moles n .

Moles and molecules:

$n = N/N_A$, where 1 mol = Avogadro's number $N_A = 6.022 \times 10^{23}$.

Ideal-gas law: $PV = nRT$ or $PV = Nk_B T$

$R = 8.31 \frac{\text{J}}{\text{mol}\cdot\text{K}}$; $k_B = 1.38 \times 10^{-23} \frac{\text{J}}{\text{K}}$



Kinetic Theory of Gases

(Section 12.4) The **kinetic theory of gases** connects macroscopic and microscopic gas properties. The **root-mean-square speed** is the square root of the mean of the squares of molecular speeds.

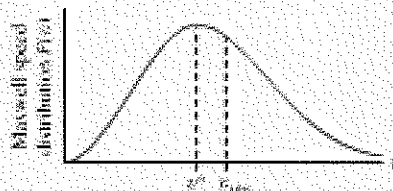
The **average kinetic energy** of an ideal gas molecule is proportional to temperature, and the gas's **total thermal energy** also increases linearly with temperature. The **Maxwell-Boltzmann distribution** describes the molecular speeds in an ideal gas. Gas molecules spread in a process known as **diffusion**.

Pressure of an ideal gas: $P = \frac{Nm\overline{v^2}}{3V}$

Average kinetic energy for gas molecules: $\overline{K} = \frac{1}{2}k_B T$

Total thermal energy: $E_{th} = N\overline{K} = \frac{1}{2}Nk_B T$

Maxwell speed distribution: $F(v) = 4\pi \left(\frac{m}{2\pi k_B T}\right)^{3/2} v^2 e^{-\frac{mv^2}{2k_B T}}$



$v_p = \sqrt{\frac{2k_B T}{m}}$

$v_{rms} = \sqrt{\frac{3k_B T}{m}}$