-30. SIMPLE HARMONIC OSCILLATIONS - ENERGY CONSIDERATIONS - TORSIONAL PENDULUM

L31. FORCED OSCILLATIONS - NORMAL MODES - RESONANCE - NATURAL FREQUENCIES - MUSICAL INSTRUMENTS

-Forced Oscillations

$$ma = -kx + F_0 \cos \omega t \qquad \rightarrow$$

$$\ddot{x} + \frac{k}{m}x = \frac{F_0}{m} \cos \omega t \qquad +$$

-the Steady State

$$x = A \cos \omega t \ \rightarrow \dot{x} = -A\omega \sin \omega t \ \rightarrow \ddot{x} = -A\omega^2 \cos \omega t \ \rightarrow$$

$$-A\omega^2 \cos \omega t + \frac{k}{m} A \cos \omega t = \frac{F_0}{m} \cos \omega t \qquad \rightarrow \qquad A\left(\frac{k}{m} - \omega^2\right) = \frac{F_0}{m}$$

$$A = \frac{F_0/m}{\omega_0^2 - \omega^2}$$ ($\omega_0 = \frac{k}{m}$: Natural Frequency)

$\omega << \omega_0 \qquad A = F_0/k$

$\omega >> \omega_0 \qquad A \rightarrow 0$

$\omega = \omega_0 \qquad A \rightarrow \infty$ **(-Resonance)**

-Coupled Oscillators

Multiple Resonance Frequency

-Musical Instruments

-String Instrument

$f_n = nf_1 \qquad f_1 \propto L, Tension, Mass$ (f_n: nth harmonic)

-Demo: Oscillating a Tube

-Cavity Instrument

$$f_n = \frac{nv_s}{2L} \qquad v_s = 340m/s$$

-Wine Glass

-Demo: Rubbing the rim to get sound

-Demo: Breaking the glass by sound

-Human Sound

-Demo: Having helium in Prof. WL's throat to change his tone （Cavity Instrument)

L32. HEAT - THERMAL EXPANSION

-Thermometric Properties

$\Delta L = \alpha L \Delta T$ (α: Linear Expansion Coefficient, unit: $1/{}^\circ C$)

-Bimetal

Control: thermostat, safety, coffee maker, thermometer,

-Cubic Expansion

$$V + \Delta V = (L + \Delta L)^3 = L^3 \left(1 + \frac{\Delta L}{L}\right)^3$$

$$(1+x)^n \approx 1 + nx \qquad x << 1 \qquad \rightarrow$$

$$= L^3 + 3L^2 \Delta L = L^3 + 3\alpha L^3 \Delta T \qquad \rightarrow$$

$\Delta V = 3\alpha V \Delta T$ ($\beta = 3\alpha$, Cubic Expansion Coefficient)

-Shrink Fitting

-Water

$0 - 4^\circ :$ $\beta < 0$ $\rightarrow$ Water has its largest density at 4°

During the winter, the bottom of pond is always 4°

L33. KINETIC GAS THEORY - IDEAL GAS LAW - ISOTHERMAL ATMOSPHERE - PHASE DIAGRAMS - PHASE TRANSITIONS

-Ideal Gas Law

$PV = nRT$ $(n:\ \#\ moles,\ R:\ universal\ gas\ constant,\ 8.3\ J/K,\ T[K])$

or $PV = NkT$

$$mole:\ 6.02\times10^{23}\ molecules$$ (Avogadro's number)

e.g. 1atm

$$P = 1.03\times10^{5}Pa \qquad T = 293^{\circ}K \qquad n = 1$$

$$V = \frac{nRT}{P} \approx 24L$$

$$moment\ transfer:\ 2mv$$ (m: molecule's mass)

$$moment\ transfer/sec\ \propto mv^2 \propto F \propto P$$ (P: independent of m)

-Isothermal Atmosphere

$$T \approx C$$ (isothermal atmosphere)

$$\rho = \frac{Nm}{V} = \frac{Pm}{kT}$$

$$\frac{dP}{dy} = -\rho g = -\frac{Pm}{kT}g$$

$$\frac{dP}{P} = -\left(\frac{mg}{kT}\right)dy = -\frac{dy}{H_0} \qquad (H_0 = \frac{kT}{mg})$$

$$\int_{P_{0\ sea\ level}}^{P_h} \frac{dP}{P} = -\frac{1}{H_0}\int_0^h dy \quad \rightarrow \quad ln\left(\frac{P_h}{P_0}\right) = -\frac{h}{H_0} \quad \rightarrow$$

$$P(h) = P_0 e^{\frac{-h}{H_0}}$$ (Atmospheric Pressure)

L34. THE WONDERFUL QUANTUM WORLD - BREAKDOWN OF CLASSICAL MECHANICS

L35. FAREWELL SPECIAL - HIGH-ENERGY ASTROPHYSICS