Physics

General Physics I

Module 1 : Mechanics basics

Module 2 : Energy and Oscillations

Potential Energy and Conservation of Energy

Potential Energy

- Conservative Force
  - Conservative Force are forces for which W1=-W2 is always ture
  - Examples:gravitational force, spring force
  - Otherwise we could not speak of their potential energies
- Gravatational Potential Energy

$$U(y) = mgy$$

- Elastic Potential Energy

$$U(x) = \frac{1}{2}kx^2$$

Conservation of Mechanical Energy

- Reading a Potential Energy Curve

Work Done on ta System by an External Force

- Power

$$P_{avg} = \frac{\Delta E}{\Delta t}$$

$$P = \frac{dE}{dt}$$

Conservation of Energy

Equilibrium

- Static equilibrium
  - $F_{net} = 0$
  - $\tau_{net} = 0$

Elasticity

- $Stress\ =\ modulus\ \times\ strian$
- Young's mudules,**E**,used for tension/compreession（拉力/压力）:

$$\frac{F}{A}\ =\ E\,\frac{\Delta L}{L}$$

- Shear mudules,**G**,used for shearing（剪切力）:
  - Δx is along a different axis than L

$$\frac{F}{A}\ =\ G\,\frac{\Delta x}{L}$$

- Bulk mudules,**B**,used for hydraulic compression（液压压力）:
  - Relates pressure to volume change

$$p\ =\ B\,\frac{\Delta V}{V}$$

Gravitation

Newton’s Law of Gravitation

- Gravitation and the principle of Superposition

$$F\ =\ G\,\frac{m_1 m_2}{r^2}$$

- hell's theorem

- Gravitation Near Earth's surface
    - Combine $F = \frac{GMm}{r^2}$ and $F = ma_g$

$$a_g = \frac{GM}{r^2}$$

$$F_N - ma_g = m(-\omega^2 R)$$

$$g = a_g - \omega^2 R$$

$a_g \approx 9.8m/s^2$
$\omega \approx 7.3 \times 10^{-5} rad/s$
$R \approx 6357km$

- Gravitation Inside Earth

$$F = \frac{GmM_{ins}}{r^2}$$

$$\rho = \frac{M_{ins}}{\frac{4}{3}\pi r^3} = \frac{M}{\frac{4}{3}\pi R^3}$$

$$F = \frac{GMm}{R^3} r$$

Gravitational Potential Energy

$$U = -\frac{GMm}{r}$$

$$K + U = \frac{1}{2}mv^2 + (-\frac{GMm}{R}) = 0$$

$$v = \sqrt{\frac{2GM}{R}}$$

Satellites: Orbits and Energy

- Escape Speed

$$m\frac{v^2}{r} = \frac{GMm}{r^2}$$

$$K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$$

$$K = -\frac{U}{2}\,(circular\,orbit)$$

$$E = K + U = -\frac{GMm}{2r}\,(circular\,orbit)$$

$$T^2 = \frac{4\pi^2}{GM}r^3$$

Oscillations

Simple Harmonic Motion

- Frequency
- Period

$$T = \frac{1}{f}$$

$$x(t) = x_m cos(\omega t + \phi)$$

$$\omega = \frac{2\pi}{T} = 2\pi f$$

$$v(t) = \frac{dx}{dt} = -\omega x_m sin(\omega t + \phi)$$

$$a(t) = \frac{dv}{dt} = \frac{d^2x}{dt^2} = -\omega^2 x_m cos(\omega t + \phi) = -\omega^2 x(t)$$

$$F = ma = -m\omega^2 x$$

$$\omega = \sqrt{\frac{k}{m}}\,(\text{Linear simple harmonic oscillation})$$

Energy in Simple Harmonic Motion\

$$U(t) = \frac{1}{2}kx^2 = \frac{1}{2}kx_m^2 cos^2(\omega t + \phi)$$

$$K(t) = \frac{1}{2}mv^2 = \frac{1}{2}kx_m^2 sin^2(\omega t + \phi)$$

$$E = U + K = \frac{1}{2}kx_m^2$$

An Angular Simple Harmonic Oscillator

$$\tau = -\kappa\theta$$

$$T = 2\pi\sqrt{\frac{I}{\kappa}}$$

Pendulums, Circular motion

$$\tau = -L(F_g sin\theta)$$

$$\alpha = -\frac{mgL}{I}\theta$$

$$\omega = \sqrt{\frac{mgL}{I}}$$

$$T = 2\pi\sqrt{\frac{F}{g}} = 2\pi\sqrt{\frac{I}{mgh}}$$

Damped Simple Harmonic Motion

$$F_d = -bv$$

$$m\frac{d^2x}{dt^2} + b\frac{dx}{dt} + kx = 0$$

$$x(t) = x_m e^{\frac{-bt}{2m}} cos(\omega' t + \phi)$$

$$\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$$

$$E(t) \approx \frac{1}{2}Kx_m^2 e^{\frac{-bt}{m}}$$

Waves

Sinusoidal Waves

- Transverse Waves

$$y(x,t) = y_m sin(kx - \omega t)$$

$$k = \frac{2\pi}{\lambda}\,(\text{angular wave number})$$

$$\omega = \frac{2\pi}{T}\,(\text{angular frequency})$$

$$f = \frac{1}{T} = \frac{\omega}{2\pi}\,(\text{frequency})$$

- Longitudinal Waves
  Sound Waves

$$B = -\frac{\Delta p}{\Delta V/V} = \rho v^2$$

$$v = \sqrt{\frac{B}{\rho}}$$

$$I = \frac{P_s}{4\pi r^2}\,(\text{Intensity})$$

Wave Speed

$$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f\,(\text{wave speed})$$

- Wave Speed on a Stretched String

$$\mu = \frac{m}{l}\,(\text{linear density})$$

$$v = \sqrt{\frac{\tau}{\mu}}\,(\text{speed})$$

Energy and Power of a Wave Travelling along a String

$$dK = \frac{1}{2} dm u^2$$

$$\frac{dK}{dt} = \frac{1}{2}\frac{dm}{dt}u^2 = \frac{1}{2}\mu v \omega^2 y_m^2 cos^2(kx - \omega t)$$

$$(\frac{dK}{dt})_{avg} = \frac{1}{4}\mu v \omega^2 y_m^2 = (\frac{dU}{dt})_{avg}$$

$$P_{avg} = \frac{d(K+U)}{dt} = 2(\frac{dK}{dt})_{avg} = \frac{1}{2}\mu v \omega^2 y_m^2$$

$$a_y = \frac{d^2y}{dt^2}$$

$$\frac{d^2y}{dx^2} = \frac{\mu}{\tau}\frac{d^2y}{dt^2}$$

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2} \text{ (wave equation)}$$

Interference of Waves

$$y'(x,t) = y_1(x,t) + y_2(x,t)$$

$$If:$$

$$y_1(x,t) = y_m sin(kx - \omega t)$$

$$y_2(x,t) = y_m sin(kx - \omega t + \phi)$$

$$s.t.$$

$$y'(x,t) = [2y_m cos\frac{1}{2}\phi] sin(kx - \omega t + \frac{1}{2}\phi)$$

- Sound Interference

$$\phi = \frac{\Delta L}{\lambda} 2\pi$$

Phasors

Standing Waves

$$If:$$

$$y_1(x,t) = y_m sin(kx - \omega t)$$

$$y_2(x,t) = y_m sin(kx + \omega t)$$

$$s.t.$$

$$y'(x,t) = [2y_m sinkx]cos\omega t$$

- Resonance
- A pipe open at both ends

$$sin(kL) = 0 \rightarrow KL = \frac{2\pi}{\lambda}L = n\pi$$

$$f = \frac{v}{\lambda} = \frac{nv}{2L}, n = 1, 2, 3, \ldots$$

- A pipe closed at one end and open at the other

$$f = \frac{v}{\lambda} = \frac{nv}{4L}, n = 1, 3, 5, \ldots$$

Doppler's Effect

$$f' = f\frac{v \pm v_D}{v \pm v_S}$$

$$sin\theta = \frac{v}{v_S}$$

Module 3 : Thermodynamics