

PHYS-201 Equation Sheet for Final Exam
(19 March 2011, CAT 61, 3:30-5:30 PM)

Simple Harmonic Oscillator; Simple and Physical Pendulum

$$\begin{aligned} F_S &= -kx & x(t) &= A \cos(\omega t + \Phi) \\ \omega &= \sqrt{\frac{k}{m}} & T &= \frac{2\pi}{\omega} = \frac{1}{f} \\ E &= K + U & E &= \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2 \\ \omega &= \sqrt{\frac{g}{L}} & \omega &= \sqrt{\frac{mgd}{I}} \end{aligned}$$

Damped Harmonic Oscillator

$$x(t) = A \exp\left(-\frac{bt}{2m}\right) \cos(\omega t + \Phi) \quad \omega = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$$

Travelling Waves; Standing Waves in Strings and Air Columns

$$\begin{aligned} y(t) &= A \sin(kx - \omega t) & k &= \frac{2\pi}{\lambda} \\ \omega &= \frac{2\pi}{T} = 2\pi f & v &= \frac{\omega}{k} = \lambda f \\ v &= \sqrt{\frac{T}{\mu}} & \mathcal{P} &= \frac{1}{2}\mu\omega^2 A^2 v \\ f_n &= \frac{n}{2L} \sqrt{\frac{T}{\mu}} & (n &= 1, 2, 3, \dots) \\ f_n &= n \frac{v}{2L} & (n &= 1, 2, 3, \dots) \\ f_n &= n \frac{v}{4L} & (n &= 1, 3, 5, \dots) \end{aligned}$$

Maxwell Equations

$$\begin{aligned}\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} &= \frac{q}{\epsilon_0} & \oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} &= 0 \\ \oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}} &= -\frac{d\Phi_B}{dt} & \oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} &= \mu_0 I + \epsilon_0 \mu_0 \frac{d\Phi_E}{dt} \\ \vec{\mathbf{F}} &= q\vec{\mathbf{E}} + q\vec{\mathbf{v}} \times \vec{\mathbf{B}} \\ \epsilon_0 &= 8.8542 \times 10^{-12} \text{ A}^2 \text{ s}^2 \text{ N}^{-1} \text{ m}^{-2} & \mu_0 &= 4\pi \times 10^{-7} \text{ N A}^{-2}\end{aligned}$$

Electromagnetic Waves; Poynting Vector; Radiation Pressure

$$\begin{aligned}\frac{E}{B} &= c & c &= \frac{1}{\sqrt{\epsilon_0 \mu_0}} \\ c &= \lambda f & f' &= f \sqrt{\frac{c+v}{c-v}} \\ \vec{\mathbf{S}} &= \frac{1}{\mu_0} \vec{\mathbf{E}} \times \vec{\mathbf{B}} & u &= \epsilon_0 E^2 = \frac{B^2}{\mu_0} \\ I &= S_{avg} = cu_{avg} & P &= \frac{S}{c}\end{aligned}$$

Diffraction & Interference on a Double Slit or Multiple Slits

$$\begin{aligned}\delta &= d \sin \theta_{bright} = m\lambda & (m &= 0, \pm 1, \pm 2, \dots) \\ \delta &= d \sin \theta_{dark} = (m + \frac{1}{2})\lambda & (m &= 0, \pm 1, \pm 2, \dots) \\ y_{bright} &= L \tan \theta_{bright} & y_{dark} &= L \tan \theta_{dark}\end{aligned}$$

Diffraction & Interference on Thin Films

$$2nt = (m + \frac{1}{2})\lambda \quad 2nt = m\lambda$$

Diffraction & Resolution of Single Slit or Circular Apertures

$$\sin \theta_{dark} = m \frac{\lambda}{a} \quad (m = \pm 1, \pm 2, \pm 3, \dots)$$
$$\theta_{min} = \frac{\lambda}{a} \quad \theta_{min} = 1.22 \frac{\lambda}{D}$$

Blackbody Radiation

$$\mathcal{P} = \sigma A e T^4 \quad \sigma = 5.7 \times 10^{-8} \text{Wm}^{-2}\text{K}^{-4}$$
$$\lambda_{max} T = 2.898 \times 10^{-3} \text{m} \cdot \text{K} \quad E_n = n h f$$
$$e = 1 \text{ (emissivity of the blackbody)} \quad h = 6.626 \times 10^{-34} \text{J} \cdot \text{s}$$

Photoelectric Effect

$$K_{max} = h f - \Phi = e \Delta V_S \quad \lambda_c = \frac{c}{f_c} = \frac{h c}{\Phi}$$
$$e = 1.602 \times 10^{-19} \text{As} \quad h c = 1240 \text{eV} \cdot \text{nm}$$
$$\hbar = \frac{h}{2\pi} = 1.055 \times 10^{-34} \text{J} \cdot \text{s} \quad c = 2.998 \times 10^8 \text{ms}^{-1}$$
$$1 \text{ eV} = 1.602 \times 10^{-19} \text{J}$$

Discrete Spectra of Atomic Gases: Rydberg Formula

$$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{n^2} \right) \quad (n = 3, 4, 5, \dots) \quad R_H = 1.097 \times 10^7 \text{m}^{-1}$$
$$E_i - E_f = h f$$

Bohr Model of the Hydrogen Atom

$$\begin{aligned}
 E = V + K &= -\frac{k_e e^2}{2r} & m_e v_n r_n &= n\hbar \quad (n = 1, 2, 3, \dots) \\
 r_n &= n^2 a_0 & E_n &= -\frac{k_e e^2}{2a_0 n^2} \quad (n = 1, 2, 3, \dots) \\
 k_e &= \frac{1}{4\pi\epsilon_0} = 8.988 \times 10^9 \text{N} \cdot \text{m}^2 (\text{As})^{-2} & e &= 1.602 \times 10^{-19} \text{As} \\
 a_0 &= \frac{\hbar^2}{m_e k_e e^2} = 5.292 \times 10^{-11} \text{m} & m_e &= 9.109 \times 10^{-31} \text{kg} = 0.511 \text{MeV} \cdot c^{-2} \\
 \frac{1}{\lambda} &= R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) & (n_f = 1 : \text{Lyman}, 2 : \text{Balmer}, 3 : \text{Paschen})
 \end{aligned}$$

Compton Effect; De Broglie Waves; Uncertainty Principle

$$\begin{aligned}
 \lambda' - \lambda_0 &= \frac{h}{m_e c} (1 - \cos \theta) & \lambda_C &= \frac{h}{m_e c} = 0.00243 \text{nm} \\
 \lambda &= \frac{h}{p} = \frac{h}{mv} \\
 v_{\text{phase}} &= \frac{\omega}{k} & v_g &= \frac{d\omega}{dk} = \frac{dE}{dp} \\
 \Delta x \cdot \Delta p_x &\geq \frac{\hbar}{2} & \Delta E \cdot \Delta t &\geq \frac{\hbar}{2}
 \end{aligned}$$

Wave Function

$$\begin{aligned}
 \int_{-\infty}^{+\infty} |\psi(x)|^2 dx &= 1 & P_{ab} &= \int_a^b |\psi(x)|^2 dx \\
 \langle x \rangle &= \int_{-\infty}^{+\infty} \psi^*(x) x \psi(x) dx & \langle f(x) \rangle &= \int_{-\infty}^{+\infty} \psi^*(x) f(x) \psi(x) dx
 \end{aligned}$$

Particle in a Box; Schrödinger Equation; Tunneling

$$\psi_n(x) = A \sin(k_n x) = A \sin\left(\frac{n\pi x}{L}\right) \quad E_n = \frac{p_n^2}{2m} = \frac{h^2}{2m\lambda_n^2} = \frac{n^2 h^2}{8mL^2}$$

$$-\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + U\psi = E\psi$$

$$T \approx 16 \frac{E}{U} \left(1 - \frac{E}{U}\right) \exp^{-2CL} \quad C = \frac{\sqrt{2m(U-E)}}{\hbar}$$

Special Theory of Relativity

$$\Delta t = \frac{\Delta t_p}{\sqrt{1 - \frac{v^2}{c^2}}} = \gamma \Delta t_p \quad L = L_p \left(1 - \frac{v^2}{c^2}\right)^{1/2} = \frac{L_p}{\gamma}$$

$$x' = \gamma(x - vt) \quad x = \gamma(x' + vt')$$

$$y' = y \quad y = y'$$

$$z' = z \quad z = z'$$

$$t' = \gamma\left(t - \frac{vx}{c^2}\right) \quad t = \gamma\left(t' + \frac{vx'}{c^2}\right)$$

$$u'_x = \frac{u_x - v}{1 - \frac{u_x v}{c^2}} \quad u_x = \frac{u'_x + v}{1 + \frac{u'_x v}{c^2}}$$

$$u'_y = \frac{u_y}{\gamma\left(1 - \frac{u_x v}{c^2}\right)} \quad u_y = \frac{u'_y}{\gamma\left(1 + \frac{u'_x v}{c^2}\right)}$$

$$u'_z = \frac{u_z}{\gamma\left(1 - \frac{u_x v}{c^2}\right)} \quad u_z = \frac{u'_z}{\gamma\left(1 + \frac{u'_x v}{c^2}\right)}$$

$$\vec{p} = \frac{m\vec{u}}{\sqrt{1 - \frac{u^2}{c^2}}} = \gamma m\vec{u} \quad E = E_R + K$$

$$E_R = mc^2 \quad K = (\gamma - 1)mc^2$$

$$E = \gamma mc^2 \quad E^2 = p^2 c^2 + (mc^2)^2$$