

Engineering Physics-PHY 1071

Some Physical Constants:

Planck's constant, $h = 6.625 \times 10^{-34} \text{ J.s}$

Speed of light in vacuum, $c = 3 \times 10^8 \text{ ms}^{-1}$

mass of proton = $1.67 \times 10^{-27} \text{ kg}$

mass of electron: $9.1 \times 10^{-31} \text{ kg}$

Boltzmann Constant, $k = 1.38 \times 10^{-23} \text{ JK}^{-1}$

Stefan's constant = $5.67 \times 10^{-8} \text{ W m}^{-1} \text{ K}^{-1}$

Wien's constant = $2.898 \times 10^{-3} \text{ mK}$

Absolute Permittivity, $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$

Absolute Permeability, $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$

1. Wave optics

Maxwell's equations

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 I + \epsilon_0 \mu_0 \frac{d\Phi_E}{dt}$$

Poynting vector, $\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$

Instantaneous energy densities $u_E = \frac{1}{2} \epsilon_0 E^2$
 $u_B = \frac{B^2}{2\mu_0}$

E - magnitude of electric field
 B - magnitude of magnetic field
 dA - magnitude of area element
 ds - magnitude of line element
 q - electric charge
 ϵ_0 - absolute permittivity
 Φ_E - electric flux
 Φ_B - magnetic flux
 I - electric current
 μ_0 - absolute permeability

Young's double slit expt.:

Condition for constructive and destructive interference

$$d \sin \theta_{\text{bright}} = m\lambda ; \quad (m = 0, \pm 1, \pm 2, \dots)$$

$$d \sin \theta_{\text{dark}} = \left(m + \frac{1}{2}\right)\lambda \quad (m = 0, \pm 1, \pm 2, \dots)$$

Linear positions of bright and dark fringes

$$y_{\text{bright}} = L \frac{m\lambda}{d} \quad (\text{small angle approximation})$$

$$y_{\text{dark}} = L \frac{\left(m + \frac{1}{2}\right)\lambda}{d} \quad (m = 0, \pm 1, \pm 2, \dots)$$

Average light intensity at a point on the screen

$$I = I_{\text{max}} \cos^2 \left(\frac{\phi}{2}\right)$$

$$I = I_{\text{max}} \cos^2 \left(\frac{\pi d \sin \theta}{\lambda}\right) \quad I = I_{\text{max}} \cos^2 \left(\frac{\pi d}{\lambda L} y\right)$$

d : distance between the two slits
 λ : wavelength of light used
 θ : angular position on the screen
 m : order number
 ϕ : phase difference
 δ : path difference
 y : linear position on the screen
 L : distance between the slit and the screen
 I_{max} : maximum intensity on the screen
 n : refractive index
 t : thickness of the film
 R : radius of curvature of lens

<p>Condition for interference in thin films in air (reflective system)</p> <p>Constructive interference:</p> $2nt = \left(m + \frac{1}{2}\right)\lambda \quad (m = 0, 1, 2, \dots)$ <p>Destructive interference:</p> $2nt = m\lambda \quad (m = 0, 1, 2, \dots)$	
<p>Radius of mth order Newton's ring</p> $r_{dark} \approx \sqrt{mR\lambda} \quad (m = 0, 1, 2, \dots)$ $r_{bright} \approx \sqrt{\frac{\left(m + \frac{1}{2}\right)R\lambda}{n_{film}}} \quad (m = 0, 1, 2, \dots)$	
<p>Anti-reflection coatings</p> $r = \frac{n_1(n_0 - n_s)\cos\delta + i(n_0n_s - n_1^2)\sin\delta}{n_1(n_0 + n_s)\cos\delta + i(n_0n_s + n_1^2)\sin\delta}$ $\delta = \left(\frac{2\pi}{\lambda_0}\right)n_1t \cos\theta_{t1}$ $R = \frac{n_1^2(n_0 - n_s)^2\cos^2\delta + (n_0n_s - n_1^2)^2\sin^2\delta}{n_1^2(n_0 + n_s)^2\cos^2\delta + (n_0n_s + n_1^2)^2\sin^2\delta}$	<p><i>r</i> – reflection coefficient <i>n</i>₁ – refractive index of the film <i>n</i>_s – refractive index of the substrate <i>n</i>₀ – refractive index of the air <i>δ</i> - phase difference <i>t</i> – thickness of the film <i>R</i>- reflectance</p>
<p>Two-Layer Anti-reflecting Films</p> $R = \left(\frac{n_0n_2^2 - n_s n_1^2}{n_0n_2^2 + n_s n_1^2}\right)^2$	
<p>Multi-Layer Anti-reflecting Films</p> $R_{max} = \left[\frac{(n_0/n_s)(n_L/n_H)^{2N} - 1}{(n_0/n_s)(n_L/n_H)^{2N} + 1}\right]^2$	
<p>Single slit diffraction: condition for minima</p> $\sin\theta_{dark} = m\frac{\lambda}{a} \quad m = \pm 1, \pm 2, \pm 3, \dots$	<p><i>a</i> : width of single slit <i>I</i>_{max} : maximum intensity [Central maxima] <i>d</i> : distance between the two slits <i>D</i> : diameter of the aperture</p>
<p>Intensity due to single slit diffraction</p> $I = I_{max} \left[\frac{\sin(\pi a \sin\theta/\lambda)}{(\pi a \sin\theta)/\lambda}\right]^2$	
<p>Intensity of two slit diffraction pattern [combined effect]</p> $I = I_{max} \cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right) \left[\frac{\sin(\pi a \sin\theta/\lambda)}{(\pi a \sin\theta)/\lambda}\right]^2$	
<p>Rayleigh's criterion: limiting angle of resolution</p> $\theta_{min} = 1.22 \frac{\lambda}{D} \text{ [for circular aperture]}$ $\theta_{min} = \frac{\lambda}{a} \text{ [for rectangular aperture]}$	
<p>Grating equation for maxima</p> $d \sin\theta_{bright} = m\lambda ; m = 0, \pm 1, \pm 2, \pm 3, \dots$	
<p>X-ray diffraction: Bragg's law</p> $2d \sin\theta = m\lambda \quad m = 1, 2, 3, \dots$	<p><i>d</i> : Inter-planar spacing in the crystal</p>

Chapter 2. LASERS AND FIBRE OPTICS

$\frac{N_2}{N_1} = e^{-(E_2-E_1)/kT}$	k : Boltzmann constant, N_1 : density of atoms with energy E_1 N_2 : density of atoms with energy E_2
$I_f = \frac{8\pi hf^3}{c^3} \left[\frac{1}{e^{\frac{hf}{kT}} - 1} \right]$	I_f : energy density of frequency f . k : Boltzmann constant c : Speed of light h : Planck's constant.
At thermal equilibrium the equation for energy density $I_f = \frac{A}{B} \left[\frac{hf}{e^{\frac{hf}{kT}} - 1} \right]$	
$\sin \theta_0 = \frac{1}{n_0} \sqrt{n_1^2 - n_2^2}$	θ_0 : acceptance angle n_0, n_1 and n_2 : Refractive indices L_s : Skip distance d : diameter of the fibre
$L_s = d \sqrt{\frac{n_1^2}{n_0^2 \sin^2 \theta} - 1}$	
$V = \frac{\pi d}{\lambda} n_0 \sqrt{n_1^2 - n_2^2}$	d : diameter of the core λ : wavelength of the light

Chapter 3. Quantum Physics

Wien's Displacement Law $\lambda_m T = 2.898 \times 10^{-3} \text{ m.K}$	λ_m : wavelength corresponding to peak intensity. T : equilibrium temperature of the blackbody.
Stefan's Law $P = \sigma A e T^4$	P : power radiated from the surface area A of the object. T : equilibrium surface temperature. σ : Stefan-Boltzmann constant. e : emissivity of the surface
Planck's law $I(\lambda, T) = \frac{2\pi hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}$	$I(\lambda, T)$: intensity or power per unit area emitted in the wavelength interval $d\lambda$ from a blackbody at the equilibrium temperature T h : Planck's constant. k_B : Boltzmann's constant c : speed of light in vacuum
Einstein's photoelectric equation $K_{max} = hf - \phi$	f : frequency of incident photon. K_{max} : kinetic energy of the most energetic photoelectron. ϕ : work function of the photocathode material.
Relativistic momentum of a particle $p = \gamma m v \quad \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$	p : momentum of the particle m : mass of the particle v : speed of the particle c : speed of light in vacuum
Relativistic kinetic energy of a particle $K = (\gamma - 1) m c^2$	
Total energy (relativistic) of the particle $E = \gamma m c^2$ $E^2 = p^2 c^2 + m^2 c^4$	

Compton shift equation $\lambda' - \lambda_o = \frac{h}{mc}(1 - \cos \theta)$	λ_o : wavelength of the incident photon. λ' : wavelength of the scattered photon, θ : angle of scattering
de Broglie wavelength, λ $\lambda = \frac{h}{p} = \frac{h}{mv} \quad p = m v = \sqrt{2 m q \Delta V}$	h : Planck's constant p : momentum of the quantum particle. m : mass of the particle v : speed of the particle q : charge of the particle ΔV : accelerating voltage
Relation between group speed and phase speed $v_g = v_p - \lambda \left(\frac{dv_p}{d\lambda} \right)$	v_g : group speed v_p : phase speed
Heisenberg uncertainty relations. $(\Delta x) (\Delta p_x) \geq h / 4\pi$ $(\Delta E) (\Delta t) \geq h / 4\pi$	Δx : uncertainty in the measurement of position x of the particle. Δp_x : uncertainty in the measurement of momentum p_x of the particle. ΔE : uncertainty in the measurement of energy E Δt : time interval in the measurement of E .

Chapter 4. Quantum Mechanics

One dimensional time independent Schrödinger equation $-\frac{\hbar^2}{2m} \frac{d^2\psi}{dx^2} + U\psi = E\psi$	\hbar : Reduced Planck's constant m : mass of the particle ψ : wave function $U(x)$: potential energy function E : total energy of the system h : Planck's constant L : length of the "box". n : integers T : tunneling probability
Expectation value of x $\langle x \rangle \equiv \int_{-\infty}^{+\infty} \psi^* x \psi dx$	
Particle in a "box" E_n - quantized energy values of the particle. $E_n = \left(\frac{h^2}{8mL^2} \right) n^2$	
Transmission coefficient $T \approx e^{-2CL} \quad C = \frac{\sqrt{2m(U-E)}}{\hbar}$	

Chapter 5. Molecules and Solids

<p>Total potential energy of the crystal</p> $U_{\text{total}} = -\alpha k_e \frac{e^2}{r} + \frac{B}{r^m}$	<p>α : Madelung constant r : separation distance between ions m : small integer</p>
<p>Probability of a particular energy state E being occupied by an electron: Fermi-Dirac distribution function</p> $f(E) = \frac{1}{\exp\left(\frac{E - E_F}{k_B T}\right) + 1}$	<p>E_F : Fermi energy k_B : Boltzmann constant</p>
<p>Density-of-states function</p> $g(E) dE = \frac{8\sqrt{2} \pi m^{\frac{3}{2}}}{h^3} E^{\frac{1}{2}} dE$	<p>m : mass of the particle h : Planck's constant</p>
<p>Fermi energy at 0K</p> $E_F(0) = \frac{h^2}{2m} \left(\frac{3n_e}{8\pi}\right)^{\frac{2}{3}}$	<p>n_e : electron density m : mass of the electron</p>
<p>Lennard-Jones potential equation</p> $U(r) = -\frac{A}{r^n} + \frac{B}{r^m}$	<p>r : inter nuclear separation distance between the two atoms A : is associated with the attractive force B : with the repulsive force J : rotational quantum number I : Moment of inertia of the molecule k : effective spring constant μ : reduced mass f : frequency of spectra n_0 : number of molecules in the $J=0$ state k_B : Boltzmann constant n, m : small integers</p>
<p>Molecule's angular momentum</p> $L = \sqrt{J(J+1)} \hbar \quad J = 0, 1, 2, \dots$	
<p>Energies of the absorbed photons in rotational transitions</p> $E_{\text{photon}} = \frac{\hbar^2}{I} J = \frac{\hbar^2}{4\pi^2 I} J \quad J = 1, 2, 3, \dots$	
<p>Vibrational energies</p> $E_{\text{vib}} = \left(v + \frac{1}{2}\right) \frac{h}{2\pi} \sqrt{\frac{k}{\mu}} \quad v = 0, 1, 2, \dots$	
<p>Combined [rotational + vibrational] spectra</p> $E_{\text{photon}} = \Delta E = hf + \frac{\hbar^2}{I} (J+1)$ $J = 0, 1, 2, \dots$	
<p>Number of molecules in an excited rotational state</p> $n = n_0 e^{\frac{-\hbar^2 J(J+1)}{2Ik_B T}}$	
<p>Intensity of spectral lines</p> $\text{Intensity} \propto (2J+1) e^{\frac{-\hbar^2 J(J+1)}{2Ik_B T}}$	

