PHYS2002-1 (Zhang)
PHYS2002-2 (Blackmon)

PHYS2002 Final Formula Sheet

Gravitational constant	g = 9.8 m/s^2
mass of proton	m_p = 1.67x10^{-27} kg
mass of electron	m_e = 9.11x10^{-31} kg
charge on proton	q_p = +1.602x10^{-19} C
charge on electron	q_e = -1.602x10^{-19} C
permeability of free space	μ_0 = 4πx10^{-7} T·m/A
permittivity of free space	ε_0 = 8.85x10^{-12} C^2/(N·m^2)
Coulomb's Law constant	k = 8.99x10^9 N·m^2/C^2 $= \frac{1}{4\pi\varepsilon_0}$
Speed of light	c = 3.00x10^8 m/s

Plank's constant h = 4.14x10^{-15} eV·s = 6.63x10^{-34} J·s $\qquad \hbar = \frac{h}{2\pi}$

Atomic mass unit u = 931.5 MeV/c^2 = 1.66x10^{-27} kg

Hydrogen (^{1}H) Atomic mass	m_H = 1.007825 u
neutron mass	m_n = 1.008665 u

Joule = J = N·m	$1eV = 1.6\times10^{-19}\,J$
Watt = W = J/s	Weber = Wb = T·m^2
Amp = A = C/s	Henry = H = V·s/A
Volt = V = J/C	Diopter = D = m^{-1}
Ohm = Ω = V/A	Bequerel = Bq = decay/s
Tesla = T = N·s/(C·m)	Curie = Ci = 3.7 x 10^{10} Bq

$$\sum \vec{F} = m\vec{a} \qquad \vec{p} = m\vec{v} \qquad W = Fd\cos\theta$$

$$x - x_0 = v_{0x}t + \frac{1}{2}a_x t^2 \qquad E_{total} = KE + EPE + GPE + \ldots$$

$$v_x - v_{0x} = a_x t \qquad KE = \frac{1}{2}mv^2 = \frac{p^2}{2m} \qquad GPE = mgy$$

$$v_x^2 - v_{0x}^2 = 2a_x(x - x_0) \qquad F_c = \frac{mv^2}{r} = ma_c \qquad T = \frac{2\pi r}{v}$$

Potential & E-field $\Delta V = E \cdot \Delta d$

Point charges

$$F = k\frac{|q_1| \cdot |q_2|}{r^2} \qquad E = k\frac{|q_1|}{r^2}$$

$$EPE = k\frac{q_1 q_2}{r} \qquad V = k\frac{q_1}{r}$$

RC Circuits $\tau = RC$

RC discharging $q = q_0 e^{-t/\tau}$

RC charging $q = q_0\left(1 - e^{-t/\tau}\right)$

Resistance $R = \rho\frac{L}{A}$

Ohm's Law $V = IR$

$$R_{series} = R_1 + R_2 + \text{K} \qquad \frac{1}{R_{\parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \text{K}$$

$$I_{series} = I_1 = I_2 = \text{K} \qquad I_{\parallel} = I_1 + I_2 + \text{K}$$

$$V_{series} = V_1 + V_2 + \text{K} \qquad V_{\parallel} = V_1 = V_2 = \text{K}$$

Power $P = IV = I^2 R = \frac{V^2}{R}$

Capacitance

$$q = CV \qquad C = \frac{\kappa \varepsilon_0 A}{d} \qquad Energy = \frac{1}{2}CV^2$$

$$E_0 = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0} \qquad E = \frac{E_0}{\kappa}$$

$$\frac{1}{C_{series}} = \frac{1}{C_1} + \frac{1}{C_2} + \text{K} \qquad C_{\parallel} = C_1 + C_2 + \text{K}$$

Electric potential energy $\Delta EPE = -W = +q\Delta V$

Forces on charged particle

$F = qE$ $\quad F = qvB\sin\theta$

Radius of motion of charged particle in uniform field $\quad r = \dfrac{mv}{qB}$

Velocity Filter $E = vB$

Force on a straight wire

$F = ILB\sin\theta$

Torque on a coil of wire

$\tau = NIAB\sin\phi$

B fields made by currents

Long, straight wire $B = \dfrac{\mu_0 I}{2\pi r}$

At center of coil of wire $B = \dfrac{N\mu_0 I}{2R}$

Solenoid $B = \mu_0 I n$

Magnetic Flux $\Phi_M = BA\cos\phi$

Motional EMF $\varepsilon = vBL$

Faraday's Law $\varepsilon = -N\dfrac{\Delta\Phi_M}{\Delta t}$

AC Generator $\varepsilon = NAB\omega\sin\omega t$

Inductance

$M = \dfrac{N_S\Phi_S}{I_P}$ $\quad L = \dfrac{N\Phi}{I}$

$\varepsilon_S = -M\dfrac{\Delta I_P}{\Delta t}$ $\quad \varepsilon = -L\dfrac{\Delta I}{\Delta t}$

Energy stored $= \dfrac{1}{2}LI^2$

Transformers

$$\frac{V_s}{V_P} = \frac{N_s}{N_P}$$

$$I_S = \frac{V_P}{V_S} I_P$$

Electromagnetic waves

$$E(t) = E_0 \sin \omega t \qquad E_{rms} = \frac{E_0}{\sqrt{2}} \qquad E = cB \qquad c = f \cdot \lambda$$

$$B(t) = B_0 \sin \omega t \qquad B_{rms} = \frac{B_0}{\sqrt{2}} \qquad \omega = 2\pi f \qquad c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

Energy density $u = \frac{\varepsilon_0}{2} E^2 + \frac{1}{2\mu_0} B^2 = \varepsilon_0 E^2 = \frac{1}{\mu_0} B^2$

$$\bar{u} = \frac{\varepsilon_0}{2} E_{rms}^2 + \frac{1}{2\mu_0} B_{rms}^2 = \varepsilon_0 E_{rms}^2 = \frac{1}{\mu_0} B_{rms}^2$$

Intensity $S = \frac{P}{A} = \frac{E}{t \cdot A} = cu \qquad \bar{S} = c\bar{u}$

$$S = cu = \frac{c\varepsilon_0}{2} E^2 + \frac{c}{2\mu_0} B^2 = c\varepsilon_0 E^2 = \frac{c}{\mu_0} B^2$$

$$f_o = f_s \left(1 \pm \frac{v_{rel}}{c}\right)$$

$$\frac{\lambda_s}{\lambda_o} = 1 \pm \frac{v_{rel}}{c}$$

Doppler shift

+ if v_{rel} is towards
- if v_{rel} is away

Malus' Law: $S = S_0 \cos^2 \theta$

Mirrors and Lenses

Law of reflection: $\theta_r = \theta_i$

Mirror/lens equation: $$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

Magnification: $$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

focal length ***f***
- *0.5 *R* for spherical mirror
- **-** for convex mirror, diverging lens
- **+** for concave mirror, converging lens

Index of refraction: $$n = \frac{c}{v} = \frac{\lambda_{vac}}{\lambda}$$

Snell's Law: $$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Total Internal reflection (critical angle): $$\sin\theta_c = \frac{n_2}{n_1}$$

Apparent depth: $$d' = d\left(\frac{n_2}{n_1}\right)$$
- n_1 contains incident ray
- n_2 contains refracted ray

Brewster's Angle: $$\tan\theta_B = \frac{n_2}{n_1}$$
- n_1 contains incident ray
- n_2 contains refracted ray

Thin film interference

$$2t + shift? = m\lambda$$ Constructive interference

$$2t + shift\ ? = m\lambda + \frac{1}{2}\lambda$$ Destructive interference

Diffraction

Double slit $m = 0, 1, 2, 3, \ldots$

$$d\sin\theta = m\lambda$$ bright fringes (constructive)

$$d\sin\theta = \left(m + \frac{1}{2}\right)\lambda$$ dark fringes (destructive)

Single slit $m = 1, 2, 3, \ldots$

$$\sin\theta = \frac{m\lambda}{W}$$ *dark* fringe of order m

Circular aperture - Resolving power - Rayleigh Criterion

$$\sin\theta \approx \theta > 1.22\frac{\lambda}{D}$$

Diffraction grating Principal maxima (bright fringes)

$$\sin\theta = m\frac{\lambda}{d}$$

Small angle approximation $\theta \approx \sin\theta \approx \tan\theta = \frac{s}{H}$

Photon Energy $E = hf = \frac{hc}{\lambda}$

Photon Momentum $p = \frac{h}{\lambda} = \frac{E}{c}$

Photoelectric effect $hf = KE_{\max} + W_0$

DeBroglie Wavelength $\lambda = \frac{h}{p}$ $p = mv$ if non-relativistic

Compton scattering $\lambda - \lambda_0 = \frac{h}{m_e c}(1 - \cos\theta)$

$$E = mc^2$$

Heisenberg Uncertainty Principle $\Delta p_y \cdot \Delta y \geq \frac{h}{4\pi}$

$\text{h} = \frac{h}{2\pi}$

$\Delta E \cdot \Delta t \geq \frac{h}{4\pi}$

Bohr model of the hydrogen-like atom

$E_i - E_f = hf$

$E_n = -(13.6eV)\frac{Z^2}{n^2}$

$r_n = (5.29 \times 10^{-11} m)\frac{n^2}{Z}$

Rydberg Constant

$R = 1.097 \times 10^7 m^{-1}$

$E_i - E_f = hf = (13.6eV)Z^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

Quantum mechanical description of atom

Subshell ordering 1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f

$2(2\ell+1)$ electrons in each subshell

$l = 0 \rightarrow s$

$l = 1 \rightarrow p$

$l = 2 \rightarrow d$

$l = 3 \rightarrow f$

$$L = \sqrt{l(l+1)}\hbar$$

$$L_z = m_l \hbar$$

$$A = Z + N \qquad r \approx \left(1.2\times10^{-15} m\right) A^{1/3}$$

mass defect $m_A + \Delta m = Zm_H + Nm_n$

binding energy $(BE) = (\Delta m)c^2$

Radioactivity

$$N = N_0 e^{-\lambda t} = N_0 \left(\frac{1}{2}\right)^n \qquad n = \frac{t}{T_{1/2}} \qquad \lambda = \frac{0.693}{T_{1/2}}$$

Activity

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

α decay $^{A}_{Z}P \rightarrow {}^{A-4}_{Z-2}D + {}^{4}_{2}He$

β⁻ decay $^{A}_{Z}P \rightarrow {}_{Z+1}^{A}D + e^{-} + \nu$

β⁺ decay $^{A}_{Z}P \rightarrow {}_{Z-1}^{A}D + e^{+} + \nu$

γ decay $^{A}_{Z}P^{*} \rightarrow {}^{A}_{Z}P + \gamma$