Phys 2426: University Physics II — Equation Sheet

Fall 2017

Values and Conversions

$g = 9.8$ N/kg $G = 6.67\times10^{-11}$ N·m²/kg² $\epsilon_0 = 8.85\times10^{-12}$ C²/N·m² $r_{\text{Earth}} = 6371$ km

$e = 1.6\times10^{-19}$ C $k = 8.99\times10^{9}$ N·m²/C² $\mu_0 = 4\pi\times10^{-7}$ N/A² $m_{\text{earth}} = 5.97\times10^{24}$ kg

$f_{\text{violet}} = 750$ THz $c = 3\times10^{8}$ m/s $f_{\text{red}} = 400$ THz 65 MPH = 29.1 m/s

Electron: $m_e = 9.11\times10^{-31}$ kg $q_e = -e$ 1 eV $= 1.6\times10^{-19}$ J

Proton: $m_p = 1.67\times10^{-27}$ kg $q_p = +e$ $h = 6.626\times10^{-34}$ J/Hz

Neutron: $m_n = 1.67\times10^{-27}$ kg $q_n = 0$ $v_{\text{sound}} \approx 340$ m/s

Math: SOH-CAH-TOA $A = \pi r^2$ $C = 2\pi r$ $V = \frac{4}{3}\pi r^3$ $A = 4\pi r^2$

Small-angle Approx ($\theta < 0.1$ rad) $\cos\theta \approx 1$ $\sin\theta \approx \tan\theta \approx \theta$ (in radians)

$f(x) \approx f_0 + \frac{\partial f}{\partial x}\Delta x$ $(1+\delta)^n \approx (1+n\delta)$ $\sqrt{1+\delta} \approx 1 + \frac{\delta}{2}$ $Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$

Vectors: $x = r\cos\theta$ $y = r\sin\theta$ **SI Prefixes:** k=10^3 M=10^6 G=10^9 T=10^{12}

$r = \sqrt{x^2+y^2}$ $\theta = \tan^{-1}\left(\frac{y}{x}\right)\underbrace{+180^\circ}_{\text{maybe}}$ c=10^{-2} m=10^{-3} μ=10^{-6} n=10^{-9} p=10^{-12}

Phys2425: $F = ma$ $\vec{v} = d\vec{x}/dt$ $\vec{a} = d\vec{v}/dt$ $\Delta x = v_i t + \frac{1}{2}at^2$ $v^2 = v_0^2 + 2a\Delta x$

$K = \frac{1}{2}mv^2$ $F_{\text{spring}} = -kx$ $U_{\text{spring}} = \frac{1}{2}kx^2$ $U_g = mgy$ $F_g = mg$ $F_B = \rho V_{\text{disp}} g$

Gravity: $F_g = G\frac{mM}{r^2}$ $F_g = mg$ $g = G\frac{M}{r^2}$ $U_G = -G\frac{mM}{r}$ $F_x = -dU/dx$

Electrostatics: $Q = \sum q_i$ $Q = \int \lambda d\ell = \lambda_{\text{avg}}\ell$ $Q = \int \sigma dA = \sigma_{\text{avg}}A$ $Q = \int \rho\, dV = \rho_{\text{avg}}V$

$F_E = k\frac{qQ}{r^2}$ $\vec{F}_E = q\vec{E}$ $E = k\frac{Q}{r^2}$ $E = \frac{2k\lambda}{r} = \frac{\lambda}{2\pi\epsilon_0 r}$ $E = 2\pi k\sigma = \frac{\sigma}{2\epsilon_0}$ **or** $E = 4\pi k\sigma = \frac{\sigma}{\epsilon_0}$

$E_x = -\frac{dV}{dx}$ $V = k\frac{Q}{r}$ $|\Delta V| = \vec{E}_{\text{avg}}\cdot\vec{\ell}$ $\Delta U_E = q\Delta V$

$\Phi_E = \iint \vec{E}\cdot d\vec{A} = E_\perp A = 4\pi k Q_{\text{enc}} = Q_{\text{enc}}/\epsilon_0$

DC Circuits: $I = \mathrm{d}Q/\mathrm{d}t$ $P = d(\text{Energy})/\mathrm{d}t$ $P = IV$ $V = IR$ $R = \rho\ell/A$

Series: $I = I_1 = I_2 = \cdots$ $V_{\text{tot}} = V_1 + V_2 + \cdots$ $R_{\text{eq}} = R_1 + R_2 + \cdots$

Parallel: $I_{\text{tot}} = I_1 + I_2 + \cdots$ $V = V_1 = V_2 = \cdots$ $R_{\text{eq}} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots\right)^{-1}$

Kirchoff: $\sum I_{\text{in}} = \sum I_{\text{out}}$ $\sum \Delta V = 0$ **Drift:** $v_d = I/(neA)$

RC Circuit: $I = I_0 e^{-t/\tau}$ $V = V_0 e^{-t/\tau}$ $\tau = RC$ $V = V_f\left(1 - e^{-t/\tau}\right)$

Magnetism:

$\vec{F}_B = q\vec{v}\times\vec{B} = qv_\perp B$ $F_B = IL_\perp B$ $\tau = NBAI\sin\theta$ $\tau_{\max} = NBAI$ $r = \frac{mv_\perp}{qB}$

$U_B = -\mu B\cos\theta$ $B_{\text{wire}} = \frac{\mu I}{2\pi r}$ $B_{\text{coil}} = N\frac{\mu I}{2r}$ $B_{\text{sol}} = \mu_0 NI/\ell$ $B_\parallel \ell = \mu_0 I_{\text{enc}}$

Mag Flux: $\Phi_B = \iint \vec{B}\cdot d\vec{A} = NBA\cos\theta$ $\Phi_B = (\mu_0 N^2 A/\ell)I$ $\Phi_B = LI$

EMF: $\mathcal{E} = -\frac{\mathrm{d}\Phi_B}{\mathrm{d}t}$ $\mathcal{E} = vB\ell$ $\mathcal{E} = -L\frac{dI}{dt}$ $\mathcal{E}_{\max} = NBA\omega$

AC Circuits: $V(t) = V_{\max}\sin(2\pi f t)$ $V_{\text{RMS}} = \frac{V_{\max}}{\sqrt{2}}$ $I_{\text{RMS}} = \frac{I_{\max}}{\sqrt{2}}$ $V_{\text{RMS}} = I_{\text{RMS}}Z$ $P_{R,\text{avg}} = \frac{P_{\max}}{2}$

$C = \kappa\epsilon_0 A/d$ $Q = CV_C$ $X_C = 1/(2\pi f C)$ Energy $= \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}Q^2/C$

$L = \mu_0 N^2 A/\ell$ $V_L = L(dI/dT)$ $X_L = 2\pi f L$ Energy $= \frac{1}{2}LI^2$

Series Impedance: $X = X_L - X_C$ $Z_{\text{eq}} = \sqrt{R^2 + X^2}$ **Transformer:** $N_2/N_1 = V_2/V_1$

Resonance: $X_L = X_C$ $f_R = \frac{1}{2\pi\sqrt{LC}}$

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Oscillations/Waves:

Fundamental: $v = f\lambda = \frac{\lambda}{T}$ $\quad f = 1/T$ $\quad \omega = 2\pi f$ $\quad k = \frac{2\pi}{\lambda}$

$x = x_{\text{max}} \sin(kx - \omega t + \phi_0)$

Specific Cases: $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ $\quad f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}$ $\quad v = \sqrt{\frac{F_T}{\mu}}$

Sound Level: $\beta = 10 \log\left(\frac{I}{I_0}\right)$ $\quad I = I_0 10^{\beta/10}$ $\quad$ **Doppler:** $\frac{\Delta f}{f} = \frac{v_{\text{rel}}}{v_{\text{wave}}}$ ($\times$ 2 if reflected)

Phase Shifts: $\Delta\ell = m\lambda$ $\quad \Delta t = mT$ $\quad$ (m = any integer for constructive)

Standing Waves:
Similar Ends: $2L = i\lambda$ $\quad f = if_0, i$ = integer
Different Ends: $4L = i\lambda$ $\quad f = if_0, i$ = odd
$2L = \left(m + \frac{1}{2}\right)\lambda$ $\quad$ (m=integer; equivalent to above)

Beat Frequency: $f_{\text{beat}} = |\Delta f| = |f_2 - f_1|$ $\quad$ **Diffraction Grating:** $m\lambda = d \sin\theta$ $\quad \tan\theta = \frac{y}{L}$

Rayleigh criterion: $\theta_{\text{min}} = 1.22\frac{\lambda}{D}$ $\quad$ **Polarizer:** $I = I_0 \cos^2\theta$

Light and Optics

Nature of Light: $E_\gamma = hf$ $\quad v_n = c/n$ $\quad \lambda_n = \lambda_0/n$

Reflection: $\theta_i = \theta_r$ $\quad$ **Refraction:** $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Brewster's Angle: $\tan\theta_p = n_2/n_1$ $\quad$ **Tot. Int. Refl.:** $\sin\theta_2 = 1$ (makes θ_1 critical angle)

Lenses/Mirrors: $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$ $\quad$ **Linear Mag.:** $M = \frac{h'}{h} = -\frac{q}{p}$

Configurations:

Projector:	Converging	Real Object outside focal point	Real Image
Magnifier:	Converging	Real Object inside focal point	Virtual Image
Reducer:	Diverging	Real Object anywhere	Virtual Image

Optical Instruments: If magnification matters, it is the angular mag. (m) of the instrument.

Angular Size: $\theta = \tan^{-1}\left(\frac{h'}{q}\right) \approx \frac{h'}{q}$ $\quad$ **Angular Mag.:** $m = \theta_{\text{with}}/\theta_{\text{without}}$

Mag. Glass: $\theta_{\text{without}} = h/d_{\text{np}}$ (Assume $d_{\text{np}} = 25$ cm) $\quad \theta_{\text{with}} = h/f$ (relaxed eyes)

$m = \frac{25\text{ cm}}{f}$ (relaxed eyes) $\quad m = \frac{25\text{ cm}}{f} + 1$ (maximum mag)

Microscope: $m = m_{\text{eyepiece}} M_{\text{objective}} = -\left(\frac{25\text{ cm}}{f_e}\right)\left(\frac{L}{f_o}\right)$

Telescope: $h' = -\theta_{\text{object}} f_o$ $\quad \theta_{\text{without}} = -h'/f_o$ $\quad \theta_{\text{with}} = h'/f_e$ $\quad m = -\frac{f_o}{f_e}$