# Phys 2426: University Physics II — Equation Sheet
# Fall 2019

(Tear off equation sheets one at a time.)

## Values and Conversions

$g = 9.8\text{ N/kg}$ $G = 6.67\times10^{-11}\text{ N·m}^2/\text{kg}^2$ $\epsilon_0 = 8.85\times10^{-12}\text{ C}^2/\text{N·m}^2$ $r_{\text{Earth}} = 6371\text{ km}$

$e = 1.6\times10^{-19}\text{ C}$ $k = 8.99\times10^9\text{ N·m}^2/\text{C}^2$ $\mu_0 = 4\pi\times10^{-7}\text{ N/A}^2$ $m_{\text{earth}} = 5.97\times10^{24}\text{ kg}$

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

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

**Proton:** $m_p = 1.67\times10^{-27}\text{ kg}$ $q_p = +e$ $1\text{ u} = 1.66\times10^{-27}\text{ kg}$

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

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

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**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** $E = 4\pi k\sigma = \frac{\sigma}{\epsilon_0}$

$E_x = -\frac{dV}{dx}$ $|\Delta V| = \vec{E}_{\text{avg}}\cdot\vec{\ell}$ $V = k\frac{Q}{r}$ $\Delta U_E = q\Delta V$ $C = \kappa\epsilon_0 A/d$ $Q = CV_C$

$\Phi_E = 4\pi k Q_{\text{enc}} = Q_{\text{enc}}/\epsilon_0$ $E = \Phi_E/A$

**DC Circuits:** $I = \text{d}Q/\text{dt}$ $P = d(\text{Energy})/\text{dt}$ $P = IV = I^2R$ $V = IR$ $R = \rho\ell/A$

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

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

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

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

**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:** $X_L = X_C$ $f_R = \frac{1}{2\pi\sqrt{LC}}$ $\omega = 2\pi f$

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### Oscillations/Waves:

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

**Oscillation:** $d = d_{\max}\sin(\omega t + \phi_0)$ **Wave:** $d = d_{\max}\sin(kx - \omega t + \phi_0)$

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

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

**Selected dB Values:** $+3$ dB $\leftrightarrow 2\times$ $+5$ dB $\leftrightarrow 3\times$ $+10$ dB $\leftrightarrow 10\times$

**Intensity:** $P = IA$ **Point Source:** $I = \frac{P}{4\pi r^2}$

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

**Standing Waves:**
- Similar Ends: $2L = m\lambda$ $f = mf_0$, $m$ = integer
- Different Ends: $4L = m'\lambda$ $f = m'f_0$, $m'$ = odd integer
- $2L = \left(m + \frac{1}{2}\right)\lambda$ ($m$=integer; equivalent to above)

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

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

### Light and Optics

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

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

**Brewster's Angle:** $\tan\theta_p = n_2/n_1$ **Tot. Int. Refl.:** $\sin\theta_2 = 1$ (makes $\theta_1$ critical angle)

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

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

$m = \frac{25\text{ cm}}{f}$ (relaxed eyes) $m = \frac{25\text{ cm}}{f} + 1$ (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:** $h' = -\theta_{\text{object}}f_o$ $\theta_{\text{without}} = -h'/f_o$ $\theta_{\text{with}} = h'/f_e$ $m = -\frac{f_o}{f_e}$