Physics 132, Sections 54/55 and 60/61, Fall 2020 – Equation Sheet

Kinematics, Forces, Newton's 2nd Law of Motion, Work and Energy

$v_x(t)=\dfrac{dx}{dt}$; $a_x(t)=\dfrac{dv_x}{dt}=\dfrac{d^2x}{dt^2}$; $K=\dfrac{1}{2}mv^2$; $U_{sp}=\dfrac{1}{2}kx^2$; $U_{grav}=mgh$; $E=K+U$

$\vec{F}_{\text{net}}=\sum\vec{F}=m\vec{a}$; $\vec{F}_{\text{spring}}=-k\Delta\vec{s}$ (along x-axis, equilibrium at $x=0$: $F_s=-kx$) ; $\left|\vec{F}_G\right|=mg$

$W_{\vec{F}}=\int\vec{F}\cdot d\vec{s}$; if $\vec{F}=\text{const}$, then $W_{\vec{F}}=\vec{F}\cdot\Delta\vec{s}$; $W_{\text{net}}=\Delta K$

Simple Harmonic Motion

$x(t)=A\cos(\omega t+\phi_0)$; $v(t)=-A\omega\sin(\omega t+\phi_0)$; $a(t)=-A\omega^2\cos(\omega t+\phi_0)=-\omega^2x(t)$

$f=1/T$; $\omega=2\pi f$; $\omega=\sqrt{k/m}$; $\omega=\sqrt{g/L}$; $\omega=\sqrt{mgL/I}$; $f_{ext}=f_0$

$x(t)=Ae^{-bt/2m}\cos(\omega t+\phi_0)$; $\omega=\sqrt{\dfrac{k}{m}-\dfrac{b^2}{4m^2}}=\sqrt{\omega_0^{\,2}-\dfrac{b^2}{4m^2}}$

Traveling Waves; Intensity Level and Doppler Effect

$k=2\pi/\lambda$; $v=\lambda f=\omega/k$; $D(x,t)=A\sin(kx\mp\omega t+\phi_0)$; $v=\sqrt{T_{string}/\mu}$ $(\mu=\text{mass/length})$

$D(r,t)=A(r)\sin(kr-\omega t+\phi_0)$; $I=P/a$ $(P=\text{energy/time})$

$\beta=(10\text{ dB})\log_{10}(I/I_0)$ with $I_0=1.0\times10^{-12}$ W/m^2 ; $f_o=f_s\left(1\pm\dfrac{v_o}{v}\right)\Big/\left(1\mp\dfrac{v_s}{v}\right)$

Superposition: Standing Waves and Interference

$D(x,t)=2A\sin(kx)\cos(\omega t)$; $\Delta\phi=\phi_2-\phi_1=2\pi\,\Delta r/\lambda+\Delta\phi_0$; $\Delta r=r_2-r_1$

$\lambda_m=\dfrac{2L}{m}$, $f_m=m\dfrac{v}{2L}$ $(m=1,2,3,\ldots)$; $\lambda_m=\dfrac{4L}{m}$, $f_m=m\dfrac{v}{4L}$ $(m=1,3,5,\ldots)$; $f_{\text{beat}}=|f_1-f_2|$

$\Delta\phi=m\cdot2\pi$ or $\Delta\phi=(m+1/2)\cdot2\pi$ $(m=0,1,2,3,\ldots)$; $A=\left|2a\cos(\Delta\phi/2)\right|$

Wave Optics: Interference and Diffraction

$y=L\tan\theta$; $d\sin\theta_m=m\lambda$ or $d\sin\theta_m=(m+1/2)\lambda$ $(m=0,1,2,\ldots)$; $\Delta y\approx\lambda L/d$

$a\sin\theta_p=p\lambda$ $(p=1,2,3,\ldots)$; $w=2\lambda L/a$; $D\sin\theta_1=1.22\lambda$

Ray Optics: Reflection and Refraction; Thin Lenses

$n=c/v$; $\theta_i=\theta_r$; $n_1\sin\theta_1=n_2\sin\theta_2$; $\sin\theta_c=n_{\text{low}}/n_{\text{high}}$

$\dfrac{1}{s}+\dfrac{1}{s'}=\dfrac{1}{f}$; $m=\dfrac{h'}{h}=-\dfrac{s'}{s}$; $m=m_1m_2$; $\dfrac{1}{f}=(n-1)\left(\dfrac{1}{R_1}-\dfrac{1}{R_2}\right)$

Pressure and Fluids

$p=F/A$; $p_{\text{liquid}}=\rho gd$; $p=p_0+p_{\text{liquid}}$; $p_g=p-p_{\text{atm}}$

Density, Number of Moles and Molar Mass

$\rho=\dfrac{M}{V}$; $n=\dfrac{N}{N_A}=\dfrac{\text{total mass}}{\text{molar mass}}$; $N=\dfrac{\text{total mass}}{\text{mass of one atom/molecule}}$

molar mass (in g/mol) = atomic/molecular mass (in u); atomic mass (in u) ≈ atomic mass number A

Ideal Gases; Temperature Scales

$pV = nRT = Nk_BT$; $p_1V_1/T_1 = p_2V_2/T_2$

$T_F = (9/5)T_C + 32$; $T_K = T_C + 273.15$; $nR = Nk_B$

Work, Heat and Thermal Energy; Adiabatic Processes; Heat Engines and Refrigerators

$W_{\text{env on gas}} = -\int_{V_i}^{V_f} p\,dV$; $W_{\text{env on gas}} = -nRT\ln(V_f/V_i)$; $W_{\text{env on gas}} = \dfrac{p_f V_f - p_i V_i}{\gamma - 1}$

$Q = Mc\Delta T = nC\Delta T$; $Q = \pm ML$; $\sum_i Q_i = 0$; $\Delta E_{\text{th}} = W_{\text{env on gas}} + Q$

$E_{th} = nC_VT$; $C_P = C_V + R$; $\gamma = C_P/C_V$; $pV^\gamma = \text{constant}$; $TV^{\gamma-1} = \text{constant}$

$E_{\text{th(gas)}} \approx (3/2)nRT$ or $(5/2)nRT$ $\Leftrightarrow$ $C_V \approx (3/2)R$ or $(5/2)R$; $E_{\text{th(solid)}} \approx 3nRT$

$\epsilon_{\text{avg}} = (1/2)mv_{\text{rms}}^2 = (3/2)k_BT$; $dS = \delta Q/T$

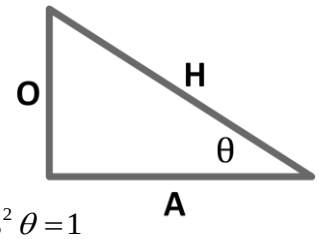
$W_{\text{out}} = Q_H - Q_C$; $\eta = W_{\text{out}}/Q_H$; $\eta_{\text{Carnot}} = 1 - T_C/T_H$; $K = Q_C/W_{\text{in}}$; $K_{\text{Carnot}} = T_C/(T_H - T_C)$

Assorted constants

$g = +9.8\ \text{m/s}^2$; $c = 3.00\times10^8\ \text{m/s}$; $v_{\text{sound}} = 343\ \text{m/s}$ (in dry air at 20 °C)

$k_B = 1.381\times10^{-23}\ \text{J/K}$; $N_A = 6.022\times10^{23}\ \text{mol}^{-1}$; $R = k_BN_A = 8.314\ \dfrac{\text{J}}{\text{mol}\cdot\text{K}} = 0.08206\ \dfrac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}}$

Trigonometry, Math and Geometry



For any quantity: $\Delta C = C_f - C_i$; $\Delta C_{ab} = C_b - C_a$

$\sin\theta = O/H$; $\cos\theta = A/H$; $\tan\theta = O/A$

$H = \sqrt{O^2 + A^2}$; $\pi\ \text{rad} = 180°$

$\sin(-\theta) = -\sin\theta$; $\cos(-\theta) = \cos\theta$; $\sin(90° - \theta) = \cos\theta$; $\sin^2\theta + \cos^2\theta = 1$

$\sin(A \pm B) = \sin A\cos B \pm \cos A\sin B$; $\cos(A \pm B) = \cos A\cos B \mp \sin A\sin B$

Small-angle approximation ($\theta \lesssim 10°$ or $\theta \lesssim 0.2$ rad): $\sin\theta \approx \tan\theta \approx \theta$ (in radians)

$ax^2 + bx + c = 0$ $\Leftrightarrow$ $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$L_{\text{circumf.}} = 2\pi r$; $A_{\text{circle}} = \pi r^2$; $A_{\text{sphere}} = 4\pi r^2$; $V_{\text{cylinder}} = A_{\text{circle}}h = \pi r^2 h$; $V_{\text{sphere}} = (4/3)\pi r^3$

Some conversion factors and SI prefixes

1 atm = 101.325 kPa = 14.70 psi
1 L = 1000 cm^3
1 m^3 = 1000 L
1 u = 1.660×10^{-27} kg
1 lb = 0.45359237 kg
1 cal = 4.186 J
1 mile (mi) = 1609.344 m
1 ft = 0.3048 m = 12 in
1 in = 2.54 cm

Name	Symbol	Multiplier
giga-	G	10^9
mega-	M	10^6
kilo-	k [lowercase]	$10^3 = 1000$
deci-	d	$10^{-1} = 0.1$
centi-	c	$10^{-2} = 0.01$
milli-	m	$10^{-3} = 0.001$
micro-	μ	10^{-6}
nano-	n	10^{-9}
pico-	p	10^{-12}