1 Formulas for 1^{st} Midterm

One dimensional motion in x:

$$x = x_0 + v_0 t + \frac{1}{2}at^2 \quad (1)$$

$$v = v_0 + at \quad (2)$$

$$v^2 = v_0^2 + 2a(x - x_0) \quad (3)$$

Projectile Motion:

x	y
$x = x_0 + v_{0x}t$	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$
$v_x = v_{0x}$	$v_y = v_{0y} - gt$
$v_x^2 = v_{0x}^2$	$v_y^2 = v_{0y}^2 - 2g(y - y_0)$

Forces:

$$\Sigma\vec{F} = m\vec{a} \quad (4)$$

$$F_s \leq \mu_s N \quad (5)$$

$$F_k = \mu_k N \quad (6)$$

Circular Motion:

$$a_c = \frac{v^2}{R} \quad (7)$$

Newtonian Gravity:

$$F = \frac{GmM}{R^2} \quad (8)$$

$$G = 6.67 \times 10^{-11}\frac{N \times m^2}{kg^2} \quad (9)$$

2 Formulas for 2^{nd} Midterm

Work and Energy:

$$W = F_{\parallel} d \tag{10}$$

$$KE_{\text{translation}} = \frac{1}{2} m v^2 \tag{11}$$

$$PE_{\text{gravity}} = mgy \tag{12}$$

$$PE_{\text{spring}} = \frac{1}{2} k x^2 \tag{13}$$

$$W = \Delta KE \tag{14}$$

$$W_{\text{nonconservative}} = \Delta KE + \Delta PE \tag{15}$$

Momentum:

$$\vec{p} = m\vec{v} \tag{16}$$

$$\vec{F}_{\text{external}} = \Delta\vec{p}/\Delta t \tag{17}$$

Rotation – Translation Correspondence:

Translation	Rotation	
x or s	θ	$\theta = s/r$
v	ω	$\omega = v/r$
a	α	$\alpha = a/r$
m	I	$I = \Sigma m r^2$
F	τ	$\tau = r_{\perp} F = r F_{\perp}$
p	L	$L = I\omega$

$$\Sigma\tau = I\alpha \tag{18}$$

$$KE_{\text{rotation}} = \frac{1}{2} I \omega^2 \tag{19}$$

$$W_{\text{rotation}} = \tau \Delta\theta \tag{20}$$

$$\tau = \Delta L/\Delta t \tag{21}$$

Static Equilibrium:

$$\Sigma F_x = 0 \tag{22}$$

$$\Sigma F_y = 0 \tag{23}$$

$$\Sigma\tau = 0 \tag{24}$$

3 Formulas for the Final

Fluids:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 \tag{25}$$

$$\text{Volume Rate of Flow} \left(\frac{m^3}{s}\right) = A_1 v_1 = A_2 v_2 \tag{26}$$

$$\text{Mass Rate of Flow} \left(\frac{kg}{s}\right) = \rho A_1 v_1 = \rho A_2 v_2 \tag{27}$$

$$F_{bouyancy} = \text{weight of fluid displaced} = \rho_{fluid} V_{displaced} g \tag{28}$$

Simple Harmonic Motion:

$$F = -kx \tag{29}$$

$$a = -\frac{k}{m}x \tag{30}$$

$$a = -\omega^2 x \tag{31}$$

$$\omega = \frac{2\pi}{\tau} = 2\pi f \tag{32}$$

Table of ω under different conditions:

	ω
Spring	$\sqrt{\frac{k}{m}}$
Phys. Pend.	$\sqrt{\frac{mgd}{I}}$
Simp. Pend.	$\sqrt{\frac{g}{l}}$

Pair-wise relations between dynamic variables:

vars	relation	comment
x-t	$x(t) = A\sin\omega t$	$x_{max} = A$
v-t	$v(t) = \omega A\cos\omega t$	$v_{max} = \omega A$
a-t	$a(t) = -\omega^2 A\sin\omega t$	$a_{max} = \omega^2 A$
x-v	$\left(\frac{x}{A}\right)^2 + \left(\frac{v}{\omega A}\right)^2 = 1$	
v-a	$\left(\frac{v}{\omega A}\right)^2 + \left(\frac{a}{\omega^2 A}\right)^2 = 1$	
a-x	$a = -\omega^2 x$	

Waves:

$$y(x,t) = A\sin(kx \mp \omega t) \tag{33}$$

$$k = \frac{2\pi}{\lambda} \tag{34}$$

$$v = \frac{\lambda}{\tau} = \lambda f \tag{35}$$

Table of v under different conditions:

	v
String	$\sqrt{\frac{T}{\mu}}$
Bulk Medium	$\sqrt{\frac{B}{\rho}}$
air	$345\frac{m}{s}$

Standing waves:

	f_n	n
closed-closed	$f_n = \frac{n}{2L}v$	n=1,2,3...
open-open	$f_n = \frac{n}{2L}v$	n=1,2,3...
open-closed	$f_n = \frac{n}{4L}v$	n=1,3,5...

Sound Level:

$$I \propto \frac{1}{d^2} \tag{36}$$

$$dB = 10log_{10}\left(\frac{I}{1 \times 10^{-12}\frac{W}{m^2}}\right) \tag{37}$$

Doppler, Beats, and Sonic Boom:

$$\frac{f_o}{v_w - v_o} = \frac{f_s}{v_w - v_s} \tag{38}$$

$$f_{beat} = |f_1 - f_2| \tag{39}$$

$$\sin\theta = \frac{v_w}{v} \tag{40}$$

Thermodynamics:

$$PV = nRT \tag{41}$$

$$< KE_{tr} >= \frac{3}{2}kT \tag{42}$$

$$v_{RMS} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}} \tag{43}$$

$$\Delta U = Q + W \tag{44}$$

Heat:

$$Q = mc\Delta T \tag{45}$$

$$Q = \pm mL \tag{46}$$

$$P = \frac{\Delta Q}{\Delta t} = k\frac{A}{L}\Delta T \tag{47}$$

$$P = e\sigma AT^4 \tag{48}$$

Thermodynamic processes:

	W	Q	ΔU	relations
iso-P	$-nR\Delta T$	$nC_P\Delta T$	$nC_V\Delta T$	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
iso-V	0	$nC_V\Delta T$	$nC_V\Delta T$	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
iso-T	$-nRT\ln\frac{V_2}{V_1}$	$nRT\ln\frac{V_2}{V_1}$	0	$P_1V_1 = P_2V_2$
adiabatic	$nC_V\Delta T$	0	$nC_V\Delta T$	$P_1V_1^\gamma = P_2V_2^\gamma$

Molar Specific Heats:

	C_V	C_P	γ
monatomic	$\frac{3}{2}$R	$\frac{5}{2}$R	$\frac{5}{3}$
diatomic	$\frac{5}{2}$R	$\frac{7}{2}$R	$\frac{7}{5}$
polyatomic	$\frac{7}{2}$R	$\frac{9}{2}$R	$\frac{9}{7}$

Efficiency and Performance:

$$eff \equiv \frac{what-you-get}{what-you-pay-for} \tag{49}$$

$$\epsilon_{engine} = -\frac{W}{Q_H} \tag{50}$$

$$Coeff_{refrig} = \frac{Q_C}{W} \tag{51}$$

Signs:

	Q_H	Q_C	W
engine	+	-	-
refrig	-	+	+

Constants:

g	$9.8\frac{m}{s^2}$
G	$6.67\times10^{-11}\frac{N\cdot m^2}{kg^2}$
ρ_{water}	$1000\frac{kg}{m^3}$
P_{atm}	$101,300Pa$
N_A	$6.02\times10^{23}\frac{molecules}{mole}$
R	$8.315\frac{J}{mole\cdot K}$
k	$k=\frac{R}{N_A}=1.38\times10^{-23}\frac{J}{K}$
$v_{sound\ in\ air}$	$345\frac{m}{s}$
σ	$5.67\times10^{-8}\frac{W}{m^2K}$