	1		I	T		
Velocity and acceleration	Special cases		Rectangular coordinates	SUVAT equation (a const)	Projectile motion	
$v = \frac{ds}{ds}$	$(a = 0)  s = s_0 + v_0 t$	$v^2 = v_0^2 + 2 \int_0^s a(s)  ds$	$\vec{r} = x\vec{\imath} + y\vec{\jmath} + z\vec{k}$	$v = v_0 + a_0 t$	$v_{0x} = v_0 \cos \theta$	
$v = \frac{dv}{dt}$		$v = v_0 + 2 \int_{s_0} u(s)  ds$		$s = s_0 + v_0 t + \frac{1}{2} a_0 t^2$	$v_{0y} = v_0 \sin \theta$	
$a = \frac{dv}{dt} = v \frac{dv}{ds}$	(const a) $v = v_0 + a_0 t$	$v = v_0 + \int_0^t a(t)  dt$	$\vec{v} = \dot{x}\vec{\imath} + \dot{y}\vec{\jmath} + \dot{z}k$	2	$a_x = 0$	
dt ds		$s = s_0 + v_0 t + $	$\vec{a} = \ddot{x}\vec{i} + \ddot{y}\vec{j} + \ddot{z}\vec{k}$	$v^2 = v_0^2 + 2a_0(s - s_0)$	$x = x_0 + v_0 t$	
	$s = s_0 + v_0 t + \frac{1}{2} a_0 t^2$	$\int_0^t \int_0^t a(t) dt dt$	$ \vec{v}  = \sqrt{\dot{x}^2 + \dot{y}^2 + \dot{z}^2}$	$s = \frac{(v + v_0)t}{2}$	$a_y = a_{0y}$	
	$v^2 = v_0^2 + 2a_0(s - s_0)$	$\int_0^\infty \int_0^\infty u(t) ut ut$	$ v  = \sqrt{x^2 + y^2 + z^2}$	2	$y = y_0 + v_{0y}t + \frac{1}{2}a_{0y}t^2$	
Normal-tangential system	<u> </u>	Cylindrical $r - \theta$ system		Circular motion	Dependent motion	
$\overrightarrow{v_{n-t}} = v\overrightarrow{u_t}$	2		$\vec{r} = r \overrightarrow{u_r}$		- Rope has constant length	
$\overrightarrow{u_h} = \overrightarrow{u_t} \times \overrightarrow{u_n}$	$\supset \overbrace{1}$	J Clo	$\vec{v} = \dot{r} \overrightarrow{u_r} + r \dot{\theta} \overrightarrow{u_{\theta}}$	Un=Ut	- Define good datum lines	
$v = \frac{ds}{dt}$	, Ut	Ur		_	(fixed position)	
		3D UZ	$\vec{a} = (\ddot{r} - r\dot{\theta}^2)\vec{u_r} +$	K Ur	- Find fixed length if possible	
$\vec{a} = \dot{v} \overrightarrow{u_t} + v \dot{\theta} \overrightarrow{u_n}$		( ) OE	$(2\dot{r}\dot{\theta} + r\ddot{\theta})\overrightarrow{u_{\theta}}$		- Divide the rope into sections if needed	
$=\dot{v}\overrightarrow{u_t} + \frac{v^2}{\rho}\overrightarrow{u_n}$	$V \cap V$		_		$L_T = s_A + s_B$	
$\left(1+\left(\frac{\mathrm{d}y}{\mathrm{d}y}\right)^{2}\right)^{1.5}$	)		$\overrightarrow{u_r} = \dot{\theta} \overrightarrow{u_{\theta}}$	7	Then $v_A + v_B = 0$	
$\rho = \frac{\left(1 + \left(\frac{\mathrm{d}y}{\mathrm{d}x}\right)^2\right)^{1.3}}{ d^2y }$			$\dot{\overrightarrow{u_{\theta}}} = -\dot{\theta}\overrightarrow{u_r}$	Un E	$a_A + a_B = 0$	
dx <sup>2</sup>		<u></u>				
Relative motion	Gravitational force	Frictional force (oppose motion)	Spring force	Equilibrium (x-y-z)	Equilibrium (n-t)	
$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$	$\vec{g} = -9.81 j \text{ms}^{-2}$	$ \operatorname{Static} F_{fsmax}  = \mu_s F_N$	$F_s = -kx$	$F_x = ma_x = m \ddot{x}$	$\sum F_n = ma_n = mv\theta$	
$\overrightarrow{v_B} = \overrightarrow{v_A} + \overrightarrow{v_{B/A}}$	$F = m\vec{g}$	Kinetic $ F_{fk}  = \mu_k F_N$	k is spring constant			
$\overrightarrow{a_B} = \overrightarrow{a_A} + \overrightarrow{a_{B/A}}$		$F_{fk} > \mu_k F_N$ velocity decrease	x is deviation from rest	$\sum F_{y} = ma_{y} = m \ddot{y}$	$=\frac{mv^2}{a}$	
		$F_{fk} = \mu_k F_N$ velocity same		$\sum F_z = ma_z = m  \ddot{z}$	$\sum_{r}^{r}$	
		$F_{fk} < \mu_k F_N$ velocity increase			$\sum F_t = ma_t = m\dot{v}$	
Equilibrium ( $r - \theta$ )	Work and motion	Work by gravitational F	Work by kinetic friction	Work by spring	Kinetic energy	
$\sum F_r = ma_r =$	$dU = \vec{F} \cdot d\vec{r} = F \cos \theta  dr$	$U_{g} = -W\Delta y$	*Against motion> negative	$U_{s} = \int_{0}^{x_{2}} -kx  dx$	$T = \frac{1}{2}mv^2$	
$m\left(\ddot{r}-r\dot{\theta}^2\right)$	$U_{P>P'} = \int_{P}^{P'} dU =$	$= -mg(y_2 - y_1)$	$U_f = -F_f \Delta x$	$\int_{x_1} -\kappa x  dx$	$T_1 + U_{1>2}^2 = T_2$	
$\sum \hat{F}_{\theta} = ma_{\theta} =$	$\int_{P}^{P'} \vec{F}  d\vec{r} = \int_{P}^{P'} F \cos \theta  ds$			$= -\frac{1}{2}k(x_2^2 - x_1^2)$	$\frac{1}{2}m_iv_{i1}^2 + \int_{s_{i1}}^{s_{i2}} \overrightarrow{F_{it}}  ds +$	
$m(2\dot{r}\dot{\theta}+r\ddot{\theta})$	Jp 1 a. Jp 1 0030 d3	*Always negative		$-\frac{1}{2}\kappa(\lambda_2-\lambda_1)$		
(= 1 . 0)					$\int_{s_{i1}}^{s_{i2}} \overrightarrow{f_{it}}  \mathrm{d}s = \frac{1}{2} m_i v_{i2}^2$	
Internal force is zero	Work done by force	Potential energy	Conservation of energy	Linear momentum	Elastic collision	
If particles connected	$U_g = -mg\Delta y$	$V_g = mgh$	$T_1 + V_1 + U_{1>2} = T_2 + V_2$	$\vec{L} = m\vec{v}$	$m_1 v_{i1} + m_2 v_{i2}$	
by inextensible cable	$U_s = -\frac{1}{2}k(s_2^2 - s_1^2)$	· 4	$  \mathbf{I}_1 + \mathbf{V}_1 + \mathbf{U}_{1>2} - \mathbf{I}_2 + \mathbf{V}_2   $ $  \mathbf{If} (\mathbf{U}_{1>2} = 0)   $	L — IIIV	$= m_1 v_{f1} + m_2 v_{f2} = m_1 v_{f1} + m_2 v_{f2}$	
$\int_{s_{t}}^{s_{l2}} \overrightarrow{f_{lt}}  ds = 0$	2	$V_s = \frac{1}{2}kx^2$	$T_1 + V_1 = T_2 + V_2$		$-m_1v_{f1}+m_2v_{f2}$	
	$U_{\rm f} = -F_{fk}\Delta S$ Conservation of	Companyation of the		Mariata a servicio	Managet	
Inelastic collision	momentum: Constant force	Conservation of momentum:	Conservation of momentum: $\sum F = 0 \mid   \Delta t = 0$	Multiple particles	Moment	
m v 1 m	$c^{t_2}$	Avg force			$\overrightarrow{M} \rightarrow \overrightarrow{r}$	
$m_1 v_{i1} + m_2 v_{i2}$	$\int_{0}^{t_{2}} \vec{F}  dt = \vec{F} \Delta t$	$\int_{0}^{\infty} \vec{F}  dt = \overrightarrow{F_{avg}} \Delta t$		$\sum_{i} m_i(\overrightarrow{\mathbf{v}_{i1}}) + \sum_{i} \int_{t_1}^{t_2} \overrightarrow{F_i}  \mathrm{dt} =$	$\overrightarrow{M_0} = \overrightarrow{r_0} \times \overrightarrow{F}$	
$= (m_1 + m_2)v_f$	$J_{t_1}$	$J_{t_1}$	$L_1 = L_2$	$\sum m_i(\overrightarrow{\mathrm{v}_{i2}})$		
Angular momentum	Principle of angular	Conservation of linear	Rigid body motions	Instantaneous centre of zero velocity		
	momentum and impulse	momentum		(Point where perpendicular vectors of velocities meet)		
$\overrightarrow{H_0} = \overrightarrow{r_0} \times m\overrightarrow{v}$	$\overrightarrow{\mathbf{H}_{01}} + \int_{t_1}^{t_2} \sum \overrightarrow{\mu_0}  dt = \overrightarrow{\mathbf{H}_{02}}$	$\sum H_{01i} = \sum H_{02i}$	- Translation	7 0 7.3		
0 0			- Fixed rotation	VM &B) 117	VA//VB	
$\left \overrightarrow{H_0}\right  = r_0 mv \sin \theta$	I → aHe		1 0 1 11	/// / 00 /	A Latichiel	
101 .0 3111.0	$\overrightarrow{\mu_0} = \frac{dH_0}{dt}$		- General motion	1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
$=r_0mv_\theta$	$\overrightarrow{\mu_0} = \frac{a_{\rm H_0}}{dt}$		- General motion	( A TE	Translational	
$= r_0 m v_\theta$	$\overrightarrow{\mu_0} = \frac{a_{H_0}}{dt}$	General motion	- General motion	Translation	Translational No IC	
$= r_0 m v_{\theta}$ Fixed rotation	-	General motion  Decompose the motion		Translation $ \overrightarrow{r_0} = \overrightarrow{r_1} + \overrightarrow{r_{01}} $	No IC	
$= r_0 m v_{\theta}$ Fixed rotation  Angular displacement $\vec{\theta}$	y↑ about a fixed	General motion  Decompose the motion  Translation > rotation	$\overrightarrow{a_{\mathrm{B}}}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$	Translational	
$=r_0 m v_{ heta}$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$	-	Decompose the motion	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{\rm A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$	No IC	
$=r_0 m v_{ heta}$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$	y↑ about a fixed	Decompose the motion	$ \overrightarrow{a_{\rm B}} $ $= \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} $ $+ \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} $		No IC	
$=r_0 m v_{ heta}$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$	y↑ about a fixed	Decompose the motion	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{\rm A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$	No IC	
$=r_0 m v_{ heta}$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{v_p} = \vec{\omega} \times \vec{r}$	y↑ about a fixed	Decompose the motion	$\overrightarrow{a_{\rm B}}$ $= \overrightarrow{a_{\rm A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}}$ $+ \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}}$ $= \overrightarrow{a_{\rm A}} - \omega^2 \overrightarrow{r_{B/A}}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$	No IC	
$= r_0 m v_\theta$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{v_p} = \vec{\omega} \times \vec{r}$ $\vec{a_p} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$	y↑ about a fixed	Decompose the motion	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change	No IC	
$= r_0 m v_\theta$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{v_p} = \vec{\omega} \times \vec{r}$ $\vec{a_p} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$	y↑ about a fixed	Decompose the motion Translation > rotation  B A Translation  Retation	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = r\alpha$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change	No IC	
$= r_0 m v_\theta$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{v_P} = \vec{\omega} \times \vec{r}$ $\vec{a_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha_c t^2$	y↑ about a fixed	Decompose the motion	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change	No IC	
$= r_0 m v_\theta$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{v_p} = \vec{\omega} \times \vec{r}$ $\vec{a_p} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$	y↑ about a fixed	Decompose the motion Translation > rotation  B A Translation  Retation	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = r\alpha$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change	No IC	
$= r_0 m v_\theta$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{v_P} = \vec{\omega} \times \vec{r}$ $\vec{a_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha_c t^2$	y about a fixed axis (20)	Decompose the motion Translation > rotation	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = r\alpha$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change	No IC	
$= r_0 m v_\theta$ Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{v_P} = \vec{\omega} \times \vec{r}$ $\vec{a_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha_c t^2$ $\omega^2 = \omega_0^2 + 2\alpha_c \theta$ Force, Moment, Angular	y about a fixed axis (20)	Decompose the motion Translation > rotation	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = r\alpha \\  a_{B/An}  = \omega^2 r$ Square moment of inertia	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change	Translational No IC   Donut moment of inertia	
	Momentum	Decompose the motion Translation > rotation		$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{a_B} = \overrightarrow{a_A}$ Circle moment of inertia $\overrightarrow{a_B} = \frac{1}{2}mR^2$	Translational No IC  Donut moment of inertia $I_G = \frac{1}{2} m(R_0 + R_i)^2$	
$\begin{aligned} &= r_0 m v_\theta \\ & \overline{\textbf{Fixed rotation}} \\ & \text{Angular displacement } \vec{\theta} \\ & \text{Angular velocity } \vec{\omega} \\ & \text{Angular acceleration } \vec{\alpha} \\ & \overrightarrow{v_P} = \vec{\omega} \times \vec{r} \\ & \overrightarrow{a_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r} \\ & \text{If } \alpha \text{ constant,} \\ & \omega = \omega_0 + \alpha_c t \\ & \theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha_c t^2 \\ & \omega^2 = \omega_0^2 + 2 \alpha_c \theta \end{aligned}$ $\begin{aligned} & \overline{\textbf{Force, Moment, Angular}} \\ & \overrightarrow{F} = \overline{m} \overrightarrow{a_G} = \sum_i m_i \overrightarrow{a_i} \\ & \overrightarrow{H_A} = \overrightarrow{r_{P/A}} \times \overrightarrow{mv} \end{aligned}$	Momentum $ \begin{array}{c} Y & \text{about a. fixed} \\ \text{axis c2D} \end{array} $ $ \begin{array}{c} P \\ \uparrow \\ \\ WI \\ H_0 = WI_o \\ H_G = wI_G \end{array} $	Decompose the motion		$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{a_B} = \overrightarrow{a_A}$ Circle moment of inertia $\overrightarrow{a_B} = \frac{1}{2}mR^2$	Donut moment of inertia $I_G = \frac{1}{2} m(R_0 + R_i)^2$ $R_0$ – outer radius	
	Momentum $ \begin{array}{c} Y & \text{about a fixed} \\ Oxis & C2D \end{array} $ $ \begin{array}{c} Y & \text{about a fixed} \\ Oxis & C2D \end{array} $ $ \begin{array}{c} Y & \text{below to a fixed} \\ Y & \text{constant a fixed} \\ Y & constant a fixed a fixe$	Decompose the motion	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} \\ + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} \\ = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} \\ + \alpha \overrightarrow{r_{B/A}} \\  a_{B/At}  = r\alpha \\  a_{B/An}  = \omega^{2} r$ $\mathbf{Square\ moment\ of\ inertia}$ $\mathbf{I}_{G} = \frac{1}{12} m l^{2}$ $\mathbf{I}_{A} = \frac{1}{3} m l^{2}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{a_B} = \overrightarrow{a_A}$ Circle moment of inertia $\overrightarrow{a_B} = \overrightarrow{a_B}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ $\overrightarrow{a_B} = \overrightarrow{a_B}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $R_{i} - \text{inner radius}$	
	$\begin{array}{c} \text{Momentum} \\ \Sigma H = wI \\ H_0 = wI_0 \\ H_G = wI_G \\ \Sigma M = I\alpha \\ M_G = I_G\alpha \end{array}$	Decompose the motion Translation > rotation	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_A} - \omega^2 \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = r\alpha \\  a_{B/At}  = r\alpha \\  a_{B/An}  = \omega^2 r$ Square moment of inertia $I_G = \frac{1}{12} m l^2$ $I_A = \frac{1}{3} m l^2$ $G - \text{centre of gravity}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{a_B} = \overrightarrow{a_A}$ Circle moment of inertia $\overrightarrow{a_B} = \overrightarrow{a_B}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ $\overrightarrow{a_B} = \overrightarrow{a_B}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$	
	$\begin{array}{c c} y & \text{about a fixed} \\ \text{OXIS C2D} \end{array}$ $\begin{array}{c} \text{Momentum} \\ \sum H = wI \\ \text{H}_0 = wI_0 \\ \text{H}_G = wI_G \\ \sum M = I\alpha \\ M_0 = I_0\alpha \text{ (pinned at O)} \end{array}$	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} \\ + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} \\ = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} \\ + \alpha \overrightarrow{r_{B/A}} \\  a_{B/At}  = r\alpha \\  a_{B/An}  = \omega^{2} r$ $\mathbf{Square\ moment\ of\ inertia}$ $\mathbf{I}_{G} = \frac{1}{12} m l^{2}$ $\mathbf{I}_{A} = \frac{1}{3} m l^{2}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $ \overrightarrow{a_B} = \frac{1}{2}mR^2 $ $ \overrightarrow{a_B} = \frac{1}{2}mR^2 $ $ \overrightarrow{a_B} = \frac{1}{2}mR^2 $ $ \overrightarrow{a_B} = \frac{1}{2}pt\pi R^4 $ $ \overrightarrow{a_B} = \sqrt{\frac{I_G}{m}} = \frac{R}{\sqrt{2}} $	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $R_{i} - \text{inner radius}$	
	$\begin{array}{c c} & \text{About a fixed} \\ & \text{OXIS C2D} \end{array}$ $\begin{array}{c} \text{Momentum} \\ & \sum H = wI \\ & \text{H}_0 = wI_0 \\ & \text{H}_G = wI_G \end{array}$ $\sum M = I\alpha \\ & M_G = I_G\alpha \\ & M_0 = I_0\alpha \text{ (pinned at O)} \\ & M_A = I_A\alpha \text{ (rolling, no slip)} \end{array}$	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_A} - \omega^2 \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = r\alpha \\  a_{B/At}  = r\alpha \\  a_{B/An}  = \omega^2 r$ Square moment of inertia $I_G = \frac{1}{12} m l^2$ $I_A = \frac{1}{3} m l^2$ $G - \text{centre of gravity}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$	
	$\begin{array}{c} \text{Momentum} \\ \hline \Sigma H = wI \\ H_0 = wI_0 \\ H_G = wI_G \\ \Sigma M = I\alpha \\ M_G = I_0\alpha \text{ (pinned at O)} \\ M_A = I_A\alpha \text{ (rolling, no slip)} \\ 2 = T_2 \end{array}$	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $\omega = \frac{v_B - v_A}{r_{B/A}}$ Work by forces	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} \\ + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} \\ = \overrightarrow{a_A} - \omega^2 \overrightarrow{r_{B/A}} \\ + \alpha \overrightarrow{r_{B/A}} \\  a_{B/At}  = r\alpha \\  a_{B/An}  = \omega^2 r$ $\mathbf{Square\ moment\ of\ inertia}$ $\mathbf{I}_G = \frac{1}{12} m l^2$ $\mathbf{I}_A = \frac{1}{3} m l^2$ $\mathbf{G} - \text{centre\ of\ gravity}$ $\mathbf{A} - \text{end\ part\ of\ square}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change	Donut moment of inertia $I_{G} = \frac{1}{2} m(R_{0} + R_{i})^{2}$ $R_{i} - \text{inner radius}$ $I_{G} = \frac{1}{2} \rho t \pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t \pi(R_{0}^{2} - R_{i}^{2})$	
	$\begin{array}{c c} & \text{About a fixed} \\ & \text{ONIS C2D} \end{array}$ $\begin{array}{c} \text{Momentum} \\ & \text{Definition} \\ & \text{Definition} \\ & \text{Definition} \\ & \text{Molecular} \\ & $	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $Work \ by \ forces$ $U_g = -mg\Delta h$	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \alpha a_{B/An} = \alpha^2 r$ Square moment of inertia $I_G = \frac{1}{12} m l^2$ $I_A = \frac{1}{3} m l^2$ $G - \text{centre of gravity}$ $A - \text{end part of square}$ $\overrightarrow{M} = \overrightarrow{r} \times \overrightarrow{F}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change	Donut moment of inertia $I_{G} = \frac{1}{2} m(R_{0} + R_{i})^{2}$ $R_{i} - \text{inner radius}$ $I_{G} = \frac{1}{2} \rho t \pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t \pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $V = V_{e} + V_{g}$	
	$\begin{array}{c} \text{Momentum} \\ \hline \Sigma H = wI \\ H_0 = wI_0 \\ H_G = wI_G \\ \Sigma M = I\alpha \\ M_G = I_0\alpha \text{ (pinned at O)} \\ M_A = I_A\alpha \text{ (rolling, no slip)} \\ 2 = T_2 \end{array}$	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $Work \ by \ forces$ $U_g = -mg\Delta h$	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} \\ + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} \\ = \overrightarrow{a_A} - \omega^2 \overrightarrow{r_{B/A}} \\ + \alpha \overrightarrow{r_{B/A}} \\  a_{B/At}  = r\alpha \\  a_{B/An}  = \omega^2 r$ $\mathbf{Square\ moment\ of\ inertia}$ $\mathbf{I}_G = \frac{1}{12} m l^2$ $\mathbf{I}_A = \frac{1}{3} m l^2$ $\mathbf{G} - \text{centre\ of\ gravity}$ $\mathbf{A} - \text{end\ part\ of\ square}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $V_{2} = \frac{1}{2}ks^{2}$	
	$\begin{array}{c c} & \text{About a fixed} \\ & \text{ONIS C2D} \end{array}$ $\begin{array}{c} \text{Momentum} \\ & \text{Definition} \\ & \text{Definition} \\ & \text{Definition} \\ & \text{Molecular} \\ & $	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $\omega = \frac{v_B - v_A}{r_{B/A}}$ Work by forces	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \alpha a_{B/An} = \alpha^2 r$ Square moment of inertia $I_G = \frac{1}{12} m l^2$ $I_A = \frac{1}{3} m l^2$ $G - \text{centre of gravity}$ $A - \text{end part of square}$ $\overrightarrow{M} = \overrightarrow{r} \times \overrightarrow{F}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $+ V_{2}$ $V_{e} = \frac{1}{2}ks^{2}$ $V_{e} = mah$	
	$\begin{array}{c c} & \text{About a fixed} \\ & \text{Oxis C2D} \\ \hline \end{array}$ $\begin{array}{c} \text{Momentum} \\ & \text{Fixed} \\ & \text{Momentum} \\ & Moment$	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $Work \ \ by \ forces$ $U_g = -mg\Delta h$ $U_e = -\frac{1}{2}k(s_2^2 - s_1^2)$	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_A} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \alpha a_{B/An} = \alpha^2 r$ Square moment of inertia $I_G = \frac{1}{12} m l^2$ $I_A = \frac{1}{3} m l^2$ $G - \text{centre of gravity}$ $A - \text{end part of square}$ $\overrightarrow{M} = \overrightarrow{r} \times \overrightarrow{F}$	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change Direction don't change	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $+ V_{2}$ $V_{e} = \frac{1}{2}ks^{2}$ $V_{e} = mah$	
	$\begin{array}{c c} & \text{About a fixed} \\ & \text{Oxis C2D} \\ \hline \end{array}$ $\begin{array}{c} \text{Momentum} \\ & \text{Fixed} \\ & \text{Momentum} \\ & Moment$	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $Work \ by \ forces$ $U_g = -mg\Delta h$	$\overrightarrow{a_{\rm B}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \alpha_{A} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \omega^{2} r$ $\begin{vmatrix} a_{B/An}   = r\alpha \\  a_{B/An}  = \omega^{2} r \end{vmatrix}$ Square moment of inertia $I_{G} = \frac{1}{12} m l^{2}$ $I_{A} = \frac{1}{3} m l^{2}$ $G - \text{centre of gravity}$ $A - \text{end part of square}$ $\overrightarrow{M} = \overrightarrow{r} \times \overrightarrow{F}$ $U_{M} = M(\theta_{2} - \theta_{1})$ Second order differential equivalent equi	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change Direction don't change	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $+ V_{2}$ $V_{2} = \frac{1}{2}ks^{2}$ $V_{3} = mgh_{G}$	
Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{\nabla_P} = \vec{\omega} \times \vec{r}$ $\vec{\alpha_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha_c t^2$ $\omega^2 = \omega_0^2 + 2\alpha_c \theta$ Force, Moment, Angular $\vec{F} = m\vec{\alpha_G} = \sum_i m_i \vec{\alpha_i}$ $\vec{H_A} = \vec{r_{P/A}} \times \vec{mV}$ $= \vec{r_{P/A}} \times \vec{L}$ $\vec{H_G} = \sum_i \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} = \sum_i \vec{M_G} M_$	Momentum $ \begin{array}{c}                                     $	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $U_g = -mg\Delta h$ $U_e = -\frac{1}{2}k(s_2^2 - s_1^2)$ $\int \overrightarrow{F}  dt = 0 \rightarrow \overrightarrow{L_1} = \overrightarrow{L_2}$		$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{Circle} \text{ moment of inertia}$ $I_G = \frac{1}{2}mR^2$ $I_G = mk_G^2$ $I = \frac{1}{2}\rho t\pi R^4$ $k_G = \sqrt{\frac{I_G}{m}} = \frac{R}{\sqrt{2}}$ $k_G - \text{radius of gyration}$ $\overrightarrow{Conservation of energy}$ $T_1 + V_1 + U_{1\rightarrow 2} = \frac{T_1}{2} + \frac{T_2}{2} + \frac{T_1}{2} + \frac{T_2}{2} + \frac{T_2}{2}$	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1} \qquad V = V_{e} + V_{g}$ $V_{e} = \frac{1}{2}ks^{2}$ $V_{g} = mgh_{G}$ $c^{2} - 4km < 0$ $2 \text{ complex } \lambda \text{s}$	
Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\overrightarrow{v_P} = \vec{\omega} \times \vec{r}$ $\overrightarrow{a_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$ $\omega^2 = \omega_0^2 + 2\alpha_c \theta$ Force, Moment, Angular $\vec{F} = \overrightarrow{ma_G} = \sum_i m_i \vec{a_i}$ $\overrightarrow{H_A} = \overrightarrow{r_{P/A}} \times \overrightarrow{mV}$ $= \overrightarrow{r_{P/A}} \times \vec{L}$ $\overrightarrow{H_G} = \sum_i \overrightarrow{M_G} \vec{M_G}$ ( $\overrightarrow{H_G} = \sum_i \overrightarrow{M_G} \vec{M_G}$ )  Momentum, impulse and	Momentum $ \begin{array}{c}                                     $	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $U_g = -mg\Delta h$ $U_e = -\frac{1}{2}k(s_2^2 - s_1^2)$ $\int \overrightarrow{F}  dt = 0 \rightarrow \overrightarrow{L_1} = \overrightarrow{L_2}$		$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{Circle} \text{ moment of inertia}$ $I_G = \frac{1}{2}mR^2$ $I_G = mk_G^2$ $I = \frac{1}{2}\rho t\pi R^4$ $k_G = \sqrt{\frac{I_G}{m}} = \frac{R}{\sqrt{2}}$ $k_G - \text{radius of gyration}$ $\overrightarrow{Conservation of energy}$ $T_1 + V_1 + U_{1\rightarrow 2} = T_2 + T_2 + T_3 + T_4 + T_4 + T_5 + T_5$	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $+ V_{2}$ $V_{e} = \frac{1}{2}ks^{2}$ $V_{g} = mgh_{G}$ $C^{2} - 4km < 0$ $2 \text{ complex } \lambda s$ $\lambda_{1} = a + bi, \lambda_{2} = a - bi, \lambda_{3} = a + bi, \lambda_{4} = a + bi, \lambda_{5} = a - bi, \lambda_{5} = a + bi, \lambda_{7} = a + bi, \lambda_$	
Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{\nabla_P} = \vec{\omega} \times \vec{r}$ $\vec{\alpha_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha_c t^2$ $\omega^2 = \omega_0^2 + 2\alpha_c \theta$ Force, Moment, Angular $\vec{F} = m\vec{\alpha_G} = \sum_i m_i \vec{\alpha_i}$ $\vec{H_A} = \vec{r_{P/A}} \times \vec{mV}$ $= \vec{r_{P/A}} \times \vec{L}$ $\vec{H_G} = \sum_i \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} = \sum_i \vec{M_G} M_$	$\begin{array}{c} \text{Momentum} \\ \Sigma H = wI \\ H_0 = wI_0 \\ H_G = wI_G \\ \Sigma M = I\alpha \\ M_G = I_G\alpha \\ M_0 = I_0\alpha \text{ (pinned at O)} \\ M_A = I_A\alpha \text{ (rolling, no slip)} \\ 2 = T_2) \\ \hline T = T_{\text{rotate}} + T_{translate} \\ = \frac{1}{2}I_Gw^2 + \frac{1}{2}mv_G^2 \\ \hline \text{angular momentum} \\ \hline \vec{H} = \vec{r} \times \vec{m} \vec{v} = Iw \\ \vec{M} = \vec{r} \times \vec{f} = I\alpha \\ \vec{H}_{G1} + \sum \int_{t_1}^{t_2} \vec{M}_G  \mathrm{dt} = \vec{H}_{G2} \end{array}$	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $U_g = -mg\Delta h$ $U_e = -\frac{1}{2}k(s_2^2 - s_1^2)$ $\int \overrightarrow{F}  dt = 0 \rightarrow \overrightarrow{L_1} = \overrightarrow{L_2}$	$\overrightarrow{a_{\mathrm{B}}} = \overrightarrow{a_{A}} + \overrightarrow{\omega} \times \overrightarrow{v_{B/A}} + \overrightarrow{\alpha} \times \overrightarrow{r_{B/A}} = \overrightarrow{a_{A}} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \alpha_{A} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \alpha_{A} - \omega^{2} \overrightarrow{r_{B/A}} + \alpha \overrightarrow{r_{B/A}} = \omega^{2} r$ Square moment of inertia $I_{G} = \frac{1}{12} m l^{2}$ $I_{A} = \frac{1}{3} m l^{2}$ G - centre of gravity A - end part of square $\overrightarrow{M} = \overrightarrow{r} \times \overrightarrow{F}$ $U_{M} = M(\theta_{2} - \theta_{1})$ Second order differential eq m\vec{x} + c\vec{x} + kx = 0  c^{2} -  x  c	$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{D} = \overrightarrow{D} = $	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $+ V_{2}$ $V_{2} = \frac{1}{2}ks^{2}$ $V_{3} = mgh_{G}$ $V_{2} = -bi$ $\lambda_{1} = a + bi  \lambda_{2} = a - bi$ $\lambda_{2} = Ae^{at}e^{bti} + Be^{at}e^{-bti}$	
Fixed rotation  Angular displacement $\vec{\theta}$ Angular velocity $\vec{\omega}$ Angular acceleration $\vec{\alpha}$ $\vec{\nabla_P} = \vec{\omega} \times \vec{r}$ $\vec{\alpha_P} = \vec{\omega} \times \vec{v} + \vec{\alpha} \times \vec{r}$ If $\alpha$ constant, $\omega = \omega_0 + \alpha_c t$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha_c t^2$ $\omega^2 = \omega_0^2 + 2\alpha_c \theta$ Force, Moment, Angular $\vec{F} = m\vec{\alpha_G} = \sum_i m_i \vec{\alpha_i}$ $\vec{H_A} = \vec{r_{P/A}} \times \vec{mV}$ $= \vec{r_{P/A}} \times \vec{L}$ $\vec{H_G} = \sum_i \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} \vec{M_G} = \sum_i \vec{M_G} M_$	Momentum $ \begin{array}{c}                                     $	Decompose the motion Translation > rotation $\omega = \frac{v_B - v_A}{r_{B/A}}$ $\overline{v_B} = \overline{v_A} + \overrightarrow{\omega} \times \overline{r_{B/A}}$ Parallel Axis Theorem $I_p = I_G + md^2$ $d - distance between P and G$ Moment of inertia can be added/subtracted $U_g = -mg\Delta h$ $U_e = -\frac{1}{2}k(s_2^2 - s_1^2)$ $\int \overrightarrow{F}  dt = 0 \rightarrow \overrightarrow{L_1} = \overrightarrow{L_2}$		$\overrightarrow{r_B} = \overrightarrow{r_A} + \overrightarrow{r_{B/A}}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{v_B} = \overrightarrow{v_A}$ $\overrightarrow{a_B} = \overrightarrow{a_A}$ Magnitude don't change Direction don't change $\overrightarrow{D} = \overrightarrow{D} = $	Donut moment of inertia $I_{G} = \frac{1}{2}m(R_{0} + R_{i})^{2}$ $R_{0} - \text{outer radius}$ $I_{G} = \frac{1}{2}\rho t\pi(R_{0}^{4} - R_{i}^{4})$ $m = \rho t\pi(R_{0}^{2} - R_{i}^{2})$ $V_{1}$ $+ V_{2}$ $V_{e} = \frac{1}{2}ks^{2}$ $V_{g} = mgh_{G}$ $C^{2} - 4km < 0$ $2 \text{ complex } \lambda s$ $\lambda_{1} = a + bi, \lambda_{2} = a - bi, \lambda_{3} = a + bi, \lambda_{4} = a + bi, \lambda_{5} = a - bi, \lambda_{5} = a + bi, \lambda_{7} = a + bi, \lambda_$	

Undamped free vibration – spring motion (horizontal)		Vertical spring Parallel / Series spring		Undamped free vibration – pendulum motion	
$\ddot{x} + \frac{k}{m}x = 0$ $\ddot{x} + w_n^2 x = 0$ $w_n = \sqrt{\frac{k}{m}}$	$X$ $= A \sin w_n t + B \cos w_n t$ $= C \sin(w_n t + \theta)$ $C = \sqrt{A^2 + B^2}  \tau = \frac{2\pi}{w_n} = \frac{1}{f}$ $\theta = \tan^{-1} \frac{B}{A}  w_n = 2\pi f$	$\begin{array}{c} \sum F_y = 0 \\ mg - k(l - l_0) = 0 \\ \delta_{eq} = l - l_0 \\ = \frac{mg}{k} \end{array}$	Parallel Series $k_{eq} = \sum_{i} k_{i} \qquad \frac{\frac{1}{k_{eq}}}{\sum_{i} \frac{1}{k_{i}}}$ $\ddot{x} + \frac{k_{eq}}{m} x = 0$	$-\operatorname{mg}\sin\theta = ma_{t}$ $s = l\theta$ $\operatorname{ml}\ddot{\theta} = -\operatorname{mg}\sin\theta$ $= ma\theta$	$= \sqrt{\frac{g}{l}}$ $v_n^2 \theta = 0$ $m$
Bar pendulum	Square pendulum	Undamped forced vibration			Damping coefficient
$w_{n} = \sqrt{\frac{3g}{2l}}$	$w_n = \sqrt{\frac{3g}{2\sqrt{2}a}}$	$F = F_0 \text{ Sintwot}$ $w_0 \text{ forcing frequency}$ $\delta_0 = \frac{F_0}{k} \text{ static deflection}$	$\ddot{x} + \frac{k}{m}x = \frac{F_0}{m}\sin w_0 t$ $x = x_c + x_p$ $x_c = A\sin w_n t + B\cos w_n t  \text{(Transient)}$ $x_p = C\sin w_0 t  \text{(steady)}$ $x_{pmax} = C = \frac{F_0}{(w_n^2 - w_0^2)m} = \frac{F_0/k}{\left(1 - \left(\frac{w_0}{w_n}\right)^2\right)} = \frac{\delta_0}{\left(1 - \left(\frac{w_0}{w_n}\right)^2\right)}$	$M = \frac{x_{pmax}}{F_0/k} = \frac{1}{1 - \left(\frac{w_0}{w_k}\right)^2}$ Magnification factor $M = \frac{1}{1 - \left(\frac{w_0}{w_k}\right)^2}$ $M = \frac{1}{1 - \left(\frac{w_0}{w_k}\right)^2$	$F_{\rm d} = -c\dot{x}$ (c is damping coefficient) $c_{\rm c} = \sqrt{\frac{k}{m}} 2m = 2mw_n$ (critical damping coeff)
Damping equation	Overdamped ( $c>c_c$ )	Critically damped ( $c=c_c$ )	Underdamped ( $c < c_c$ )		Electrical circuit analogy
$m\ddot{x} + c\dot{x} + kx = 0$ $x = e^{\lambda t}$ $e^{\lambda t}(m\lambda^2 + c\lambda + k) = 0$ $\lambda = \frac{-c \pm \sqrt{c^2 - 4km}}{2m}$ $x = Ae^{\lambda_1 t} + Be^{\lambda_2 t}$	2 real, negative $\lambda s$ No vibration $\left(\frac{c}{2m}\right)^2 - \frac{k}{m} > 0$	one real $\lambda$ No vibration $c_{\rm c}$ is smallest c which system won't vibrate $\left(\frac{\rm c}{2\rm m}\right)^2 - \frac{k}{m} = 0$ $x = (A+Bt)e^{\lambda t}$	2 complex $\lambda s$ $\left(\frac{c}{2m}\right)^2 - \frac{k}{m} < 0$ $x = D\left[e^{-\frac{c}{2m}t}\sin(w_d t + \theta)\right]$ $w_d = w_n \sqrt{1 - \left(\frac{c}{c_c}\right)^2}$ $\ln\left(\frac{x_1}{x_2}\right) = \frac{2\pi\left(\frac{c}{c_c}\right)}{\sqrt{1 - \left(\frac{c}{c_c}\right)^2}}$ $\tau_d = \frac{2\pi}{w_d} > \tau$	$x = x_0 e^{-\frac{c}{2m}t}$	Mass <-> inductance Damp coeff. <-> resistance Spring con. <-> 1/capacitance Force <-> voltage Displacement <-> charge Velocity <-> current