Formulae:

Vectors: \( \mathbf{A} = A_x \mathbf{i} + A_y \mathbf{j} \) with: \( \mathbf{i} \) (j) = the unit vector along the x (y) axis

Trigonometry: \( \sin \theta = b/c; \cos \theta = a/c; \tan \theta = b/a \) “slope” of \( \theta \)
thus: \( b = c \sin \theta, \quad a = c \cos \theta, \quad b = a \tan \theta \),
\( a^2 + b^2 = c^2 \), hence: \( \sin^2 \theta + \sin^2 \theta = 1 \)
\( \sin(90^\circ - \theta) = \sin(-\theta), \cos \theta = \cos(\theta) \)

Components: (if \( \theta \equiv \) angle with the \( +x \)-axis!)
\( A_x = A \cos \theta, \quad A_y = A \sin \theta, \quad \mathbf{A} = (A_x, A_y) \)

Scalar Product (“Dot” Product): 
\( (\mathbf{A} \cdot \mathbf{B}) = A_x B_x + A_y B_y = AB \cos \theta_{\mathbf{A}, \mathbf{B}} \)

\( \mathbf{B} \)

Circle: circumference = \( 2\pi R \); Area = \( \pi R^2 \); \( \pi = 3.1416 \)

Sphere: surface = \( 4\pi R^2 \); volume = \( 4\pi R^3/3 \)

Quadratic Equation: \( ax^2 + bx + c = 0 \); constants \( a, b, \) and \( c \)

Solutions: \( x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a} \)

Prefixes:
\( f = 10^{-15}, \quad p = 10^{-12}, \quad n = 10^{-9}, \quad \mu = 10^{-6}, \quad m = 10^{-3}, \quad k = 10^3, \quad M = 10^6, \quad G = 10^9, \quad T = 10^{12}, \quad P = 10^{15} \)

Constants:
\( g = 9.80 \text{ m/s}^2; \quad M_E = 5.98 \times 10^{24} \text{ kg}; \quad R_E = 6.37 \times 10^6 \text{ m}; \quad N_A = 6.022 \times 10^{23} \text{ mol}^{-1} \)

Uncertainty:
\( S = A + B \Leftrightarrow \Delta S = \sqrt{\Delta A^2 + \Delta B^2}; \quad S = c \Leftrightarrow \Delta S = c \Delta A; \quad S = A \cdot B \Leftrightarrow \Delta S = S \left( \frac{\Delta A}{A} \right)^2 + \left( \frac{\Delta B}{B} \right)^2 \)

Kinematics:
the “motion”; position \( s \) as function of time \( t \)
\( s = s(t) = (x, y) \) (position)

velocity \( v \); acceleration \( a \):
\( v = ds/dt = (v_x, v_y); \quad \text{speed } v = |v|; \quad a = dv/dt = (a_x, a_y) \)

Linear motion with constant \( a \):
\( v = v_0 + at, \quad s = s_0 + v_0 t + \frac{1}{2}at^2; \quad v^2 = v_0^2 + 2a(s - s_0) \)

rotation angle \( \theta \) (radians; rotation radius \( R \)):
\( \theta = s/(arc \text{ length})/R = \theta(t) \) (angular position)

angular velocity \( \omega \):
\( \omega = d\theta/dt = v/R \) (speed along the circle)

angular acceleration \( \alpha \):
\( \alpha = d\omega/dt = a/R \) (parallel to circle)

Circular motion (radius \( R \)) with constant \( \alpha \):
\( \omega = \omega_0 + \alpha t; \quad \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2; \quad \omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0) \)

Circular motion – centripetal acceleration \( a_c \):
\( a_c = v^2/R \) (radially inwards)

Center-of-Gravity of system (mass \( M \)):
\( \mathbf{r}_{cg} = \sum m_i \mathbf{r}_i / \sum m_i = \sum m_i \mathbf{r}_i / M; \quad x_{cg} = \sum m_i x_i / M; \quad y_{cg} = \sum m_i y_i / M \)

Moment of Inertia \( I \):
\( I = \Sigma m_i r_i^2; \quad r_i = \text{distance between rotation axis and cg of } m_i; \quad \text{axis through cg: } I = ML^2/12 \)

thin uniform rod or slab (\( M, L \)), axis \perp \) rod:

\( \text{hollow cylinder (} M, R_\text{in}, R_\text{out} \), axis is cylinder axis: \)
\( I = \frac{1}{2} M (R_\text{in}^2 + R_\text{out}^2) \) (= \( \frac{1}{2} MR^2 \) solid disk!)

\( \text{uniform solid sphere (} M, R \), axis through center: \)
\( I = 2MR^2/5 \)

Forces \([\text{N}=\text{kgm/s}^2]\) and consequences:
\( \mathbf{F}_{\text{Net}} = \sum \mathbf{F}_i = ma; \quad \mathbf{F}_{\text{on } \mathbf{A}} = -\mathbf{F}_{\text{on } \mathbf{A}}; \quad \tau_{\text{Net}} = \sum \tau_i = I \alpha \)

Force of Gravity between \( M \) and \( m \), at center-to-center distance \( r \):
\( \mathbf{F}_G = GMm/r^2 \) (–) (attractive!) \( G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \); near sea level: \( \mathbf{F}_G = mg(-j) \) (downwards); \( g = 9.80 \text{ m/s}^2 \)

Force of a Spring (spring constant \( k \)):
\( \mathbf{F}_S = -k \Delta \mathbf{L} \) (opposes compression/stretch \( \Delta \mathbf{L} \))

Force of an Elastic solid bar of length \( L \) and cross sectional area \( A \):
\( \mathbf{F}_S = -YA(\mathbf{A}\Delta \mathbf{L}/L) \) (opposes compression/stretch \( \Delta \mathbf{L} \))
\( Y \equiv \) the material’s Young’s modulus (units: \( \text{N/m}^2 \))

Normal Force \( n \): a reaction force
\( \mathbf{n} = \mathbf{A} \times \mathbf{F} \) perpendicular to (\perp) surfaces

Direction: // to surface and opposing the motion

Force of Friction
\( \mu = \text{friction coefficient; } n = \text{normal force} \)

Note: static friction is a reaction force:
\( f_s \leq \mu_n \)

Kinetic friction:
\( f_k = \mu_n \)

Torque by \( \mathbf{F} \):
\( \tau = RF\sin \theta_{\mathbf{R} \mathbf{F}} = RF_x = R_L F; \quad \tau_{\text{Net}} = \Sigma \tau_i = I \alpha = dL/dt; \quad \mathbf{R} \) points from the rotation axis to the point in which \( \mathbf{F} \) acts; sign of \( \tau \): Counter Clock Wise = +, Clock Wise = –

Equilibrium:
\( \Sigma \mathbf{F}_i = 0 \) and \( \Sigma \tau_i = 0 \)