SUMMARY OF CHAPTER 1 to 9 (Beer and Johnston, 2004)

Chapter 1 *Dimensions & Units*	**Acceleration:** ft/s^2 → 0.3048 m/s^2 in/s^2 → 0.0254 m/s^2 **Area:** ft^2 → 0.0929 m^2 in^2 → 645.2 mm^2 **Energy:** ft·lb → 1.356 J **Force: $F = ma$** kip → 4.448 kN lb → 4.448 N 1N → 1 kgm/s^2 **Length:** ft → 0.3048 m in → 25.40mm mi → 1.609 km **Mass:** oz → 28.35 g lb mass → 0.4536kg slug → lb·s^2/ft → 14.59 kg ton → 907.2 kg **Moment of a force:** lb·ft → 1.356 N·m lb·in → 0.1130 N·m **Moment of inertia:** area : in^4 → 0.4162*10^6 mm^4 mass: lb·ft·s^2 → 1.356 kg·m^2 **Momentum:** lb·s → 4.448 kg·m/s **Work:** 1J → 1Nm ft·lb → 1.356 J **Power:** ft·lb/s → 1.356 W hp → 745.7 W **Pressure or stress:** lb/ft^2 → 47.88 Pa lb/in^2 (psi) → 6.895 kPa **Velocity:** ft/s → 0.3048 m/s in/s → 0.0254 m/s mi/h (mph) → 0.4470 m/s mi/h (mph) → 1.609 km/h **Volume:** ft^3 → 0.02832 m^3 in^3 → 16.39 cm^3 **Weight:** $W = mg$
Chapter 2 *Statics of Particles*	**Rectangular components :** $\mathbf{F_x} = F_x\mathbf{i}$ $\quad \mathbf{F_y} = F_y\mathbf{j}$ $\mathbf{F} = F_x\mathbf{i} + F_y\mathbf{j}$ **where** $F_x = F\cos\theta$ $\quad F_y = F\sin\theta$ direction angle: $\tan\theta = F_y / F_x$ $\quad$ magnitude: $F = \sqrt{F_x^2 + F_y^2}$ **Resultant:** $R_x = \Sigma F_x$ $\quad R_y = \Sigma F_y$ **Forces in space:** $F_x = F\cos\theta_x$ $\quad F_y = F\cos\theta_y$ $\quad F_z = F\cos\theta_z$ $\mathbf{F} = F_x\mathbf{i} + F_y\mathbf{j} + \mathbf{F_z} = F_z\mathbf{k}$ **or** $\mathbf{F} = F(\cos\theta_x\mathbf{i} + \cos\theta_y\mathbf{j} + \cos\theta_z\mathbf{k})$ $\boldsymbol{\lambda} = \cos\theta_x\mathbf{i} + \cos\theta_y\mathbf{j} + \cos\theta_z\mathbf{k}$ $\quad \cos^2\theta_x + \cos^2\theta_y + \cos^2\theta_z = 1$ $F = \sqrt{F_x^2 + F_y^2 + F_z^2}$ $\quad \cos\theta_x = F_x / F$ $\quad \cos\theta_y = F_y / F$ $\quad \cos\theta_z = F_z / F$ **Resultant:** $R_x = \Sigma F_x$ $\quad R_y = \Sigma F_y$ $\quad R_z = \Sigma F_z$
Chapter 3 *Equivalent Systems of Forces*	**Vector Product:** $\mathbf{V} = \mathbf{P} \times \mathbf{Q}$ $\quad V = PQ\sin\theta$ $\quad \mathbf{Q} \times \mathbf{P} = -(\mathbf{P} \times \mathbf{Q})$ $\quad \mathbf{i} \times \mathbf{i} = 0$ $\quad \mathbf{i} \times \mathbf{j} = \mathbf{k}$ $\quad \mathbf{j} \times \mathbf{i} = -\mathbf{k}$ **Rectangular components of vector product:** $V_x = P_y Q_z - P_z Q_y$ $\quad V_y = P_z Q_x - P_x Q_z$ $\quad V_z = P_x Q_y - P_y Q_x$ $\mathbf{V} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ P_x & P_y & P_z \\ Q_x & Q_y & Q_z \end{vmatrix}$ **Moment of a force:** $\mathbf{M}_O = \mathbf{r} \times \mathbf{F}$ $\quad M_O = rF\sin\theta = Fd$ $M_x = yF_z - zF_y$ $\quad M_y = zF_x - xF_z$ $\quad M_z = xF_y - yF_x$ $\mathbf{M}_O = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ x & y & z \\ F_x & F_y & F_z \end{vmatrix}$ $\quad \mathbf{M}_B = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ x_{A/B} & y_{A/B} & z_{A/B} \\ F_x & F_y & F_z \end{vmatrix}$ **Scalar Product:** $\mathbf{V} = \mathbf{P} \cdot \mathbf{Q}$ $\quad V = PQ\cos\theta$ $\quad \mathbf{P} \cdot \mathbf{Q} = P_xQ_x + P_yQ_y + P_zQ_z$ **Moment of a force about an axis:** $M_{OL} = \boldsymbol{\lambda} \cdot \mathbf{M}_O = \boldsymbol{\lambda} \cdot (\mathbf{r} \times \mathbf{F})$ **Equivalent system of forces**: $\Sigma\mathbf{F} = \Sigma\mathbf{F}'$ and $\Sigma\mathbf{M}_O = \Sigma\mathbf{M}'_O$
Chapter 4 Equilibrium Rigid Bodies	**Equilibrium equations:** $\Sigma\mathbf{F} = 0$ $\quad \Sigma\mathbf{F_x} = 0$ $\quad \Sigma\mathbf{F_y} = 0$ $\quad \Sigma\mathbf{F_z} = 0$ $\Sigma\mathbf{M}_O = (\mathbf{r} \times \mathbf{F}) = 0$ $\quad \Sigma\mathbf{M_x} = 0$ $\quad \Sigma\mathbf{M_y} = 0$ $\quad \Sigma\mathbf{M_z} = 0$

Chapter 5 *Centroids and Center of gravity*	**Center of gravity of a 2 dimensional body:** $W = \int dW$ $xW = \int x\,dW$ $yW = \int y\,dW$ **Centroid of an area:** $xA = \int x\,dA$ $yA = \int y\,dA$ **First Moments:** $Q_y = xA$ $Q_x = yA$ **Center of gravity of composite body:** $X\,\Sigma W = \Sigma xW$ $Y\,\Sigma W = \Sigma yW$ $Q_y = X\,\Sigma A = \Sigma xA$ $Q_x = Y\,\Sigma A = \Sigma yA$ **Determination of Centroid by integration:** $Q_y = xA = \int x_{el}\,dA$ $Q_x = yA = \int y_{el}\,dA$ **Theorem Pappus-Guldinus :** $A = 2\pi yL$ $V = 2\pi yA$ **Center of gravity 3 dimensional body:** $xW = \int x\,dW$ $yW = \int y\,dW$ $zW = \int z\,dW$ **Centroid of a Volume: :** $xV = \int x\,dV$ $yV = \int y\,dV$ $zV = \int z\,dV$ **Center of gravity of composite body:** $X\,\Sigma W = \Sigma xW$ $Y\,\Sigma W = \Sigma yW$ $Z\,\Sigma W = \Sigma zW$ $X\,\Sigma V = \Sigma xV$ $Y\,\Sigma V = \Sigma yV$ $Z\,\Sigma V = \Sigma zV$ **Determination of Centroid by integration:** $xV = \int x_{el}\,dV$ $yV = \int y_{el}\,dV$ $zV = \int z_{el}\,dV$
Chapter 7 *Forces in Beams and Cables*	**Relations among load, shear, and bending moment:** $dV / dx = -w$ or $V_D - V_C = -$ (area under load curve between C and D) $dM / dx = V$ $M_D - M_C =$ area under shear curve between C and D) **Cables with distributed loads:** **Catenary:** Tension: $T = \sqrt{T_0^2 + W^2}$ $s = c \sinh x/c$ $\tan \theta = W / T_0$ $y = c \cosh x/c$ $y^2 - s^2 = c^2$ **Parabolic cable:** $T_0 = wc$ $W = ws$ $T = wy$ $y = wx^2 / 2T_0$
Chapter 8 *Static Friction*	**Static and kinetic friction:** $F_m = \mu_s N$ $F_k = \mu_k N$ **Angles of friction:** $\tan \varphi_s = \mu_s$ $\tan \varphi_k = \mu_k$ **Belt friction:** $\ln T_2 / T_1 = \mu_s \beta$ $T_2 / T_1 = e^{\mu_s \beta}$
Chapter 9 *Distributed forces & Moments of Inertia*	**Moment of inertia of an <u>Area</u>:** **Rectangular moments of inertia:** $I_x = \int y^2\,dA$ $I_y = \int x^2\,dA$ **Polar moment of inertia:** $J_O = \int r^2\,dA$ $J_O = I_x + I_y$ **Radius of gyration:** $k_x = \sqrt{I_x/A}$ $k_y = \sqrt{I_y/A}$ $k_z = \sqrt{I_z/A}$ **Parallel axis theo. :** $I = I + Ad^2$ $J_O = J_c + Ad^2$ **Product of inertia:** $I_{xy} = \int xy\,dA$ $I_{xy} = I_{x'y'} + xyA$ $I_{x'} = (I_x + I_y)/2 + (I_x - I_y)/2 \cos 2\theta - I_{xy} \sin 2\theta$ $I_{y'} = (I_x + I_y)/2 + (I_x - I_y)/2 \cos 2\theta + I_{xy} \sin 2\theta$ $I_{x'y'} = (I_x + I_y)/2 \sin 2\theta + I_{xy} \cos 2\theta$ **Principal axes:** $\tan 2\theta_m = -2 I_{xy} / I_x - I_y$ **Moment of inertia of <u>Mass</u>:** $I = \int r^2\,dm$ $k = \sqrt{I/m}$ $I_x = \int (y^2 + z^2)\,dm$ $I_y = \int (z^2 + x^2)\,dm$ $I_z = \int (x^2 + y^2)\,dm$ **Parallel axis theo.** : $I = \bar{I} + md^2$ **Moments of Inertia Thin Plates:** $I_{AA'} = 1/12\,ma^2$ $I_{BB'} = 1/12\,mb^2$ $I_{CC'} = I_{AA'} + I_{BB'} = 1/12\,m(a^2 + b^2)$ for circular plate: $I_{AA'} = I_{BB'} = \frac{1}{4} mr^2$ $I_{CC'} = I_{AA'} + I_{BB'} = \frac{1}{2} mr^2$ **Moment of inertia with respect to arbitrary axis:** $I_{xy} = \int xy\,dm$ $I_{yz} = \int yz\,dm$ $I_{zx} = \int zx\,dm$ $I_{OL} = I_x \lambda_x^2 + I_y \lambda_y^2 + I_z \lambda_z^2 - 2I_{xy}\lambda_x\lambda_y - 2I_{yz}\lambda_y\lambda_z - 2I_{zx}\lambda_z\lambda_x$ **Principal axes of inertia** **Principal Moments of Inertia** $I_{OL} = I_{x'}\lambda_{x'}^2 + I_{y'}\lambda_{y'}^2 + I_{z'}\lambda_{z'}^2$ $K^3 - (I_x + I_y + I_z)K^2 + (I_x I_y + I_y I_z + I_z I_x - I_{xy}^2 - I_{yz}^2 - I_{zx}^2)K$ $- (I_x I_y I_z - I_x I_{yz}^2 - I_y I_{zx}^2 - I_z I_{xy}^2 - 2 I_{xy} I_{yz} I_{zx}) = 0$