Summary Notes for Exam #1

EQUILIBRIUM EQUATIONS

$\sum F_X = 0$; $\sum F_Y = 0$; $\sum M_Z = 0$

EQUATION OF CONDITION

The internal bending moment at an internal hinge equals zero.

TRUSS ANALYSIS

Method of Joints: Two equilibrium equations per truss joint.

Method of Sections: Three equilibrium equations per truss section.

<u>Zero Force Members:</u>

(a) If only two non-collinear members are connected to a joint that has no external loads or reactions applied to it, then the force in both members is zero.

(b) If three members, two of which are collinear, are connected to a joint that has no external forces or reactions applied to it, then the force in the member that is not collinear is zero.

AXIAL, SHEAR AND BENDING EQUATIONS

Divide the structure into segments, choose an appropriate origin for measuring the length of the segment x, and establish the limits on x. (<u>NOTE</u>: Add appropriate subscript to x to avoid confusion between various segments.) Draw a FBD for the segment, exposing the internal axial, shear and bending moments at the segment cut. Using the equilibrium equations, establish the equations for the internal axial, shear, and bending moments as a function of distance x. Repeat procedure for each segment. Draw the axial, shear, and bending moment diagrams by simply plotting the generated equations and make sure that connected segment values match appropriately and that external boundary conditions are satisfied. If they are not satisfied, write a brief statement indicating that you know an error exists, but due to time constraints, you cannot determine the source of your error.

DISPLACEMENT CALCULATIONS

We studied the principle of virtual forces for calculating the structure displacements at a single point. This principle states that the external virtual work ($\bar{W}_V$) equals the internal virtual work or virtual strain energy ($\bar{U}_V$); i.e. $\bar{W}_V = \bar{U}_V$. In generating the external and internal virtual works, a unit virtual force or couple is applied at the desired displacement or rotation point in the assumed direction of the displacement or rotation. These calculations can be expressed as

$$1 \bullet \Delta = \sum_i \left[F_{Vi} (F_i L_i)/EA_i\right] \qquad \text{TRUSS ANALYSIS}$$

$$1 \bullet \Delta = \sum_i \left[\int (M^{\delta}_{Vi} (M_i/EI_i)) \, dx \right] \qquad \text{BEAM OR FRAME ANALYSIS}$$

$$1 \bullet \theta = \sum_i \left[\int (M^{\theta}_{Vi} (M_i/EI_i)) \, dx \right] \qquad \text{BEAM OR FRAME ANALYSIS}$$

in which Δ = desired displacement; θ = desired rotation; F_{Vi} = virtual axial force for member i due to a unit virtual force at Δ; F_i = real axial force for member i; M^{δ}_{Vi} = virtual moment equation of segment i due to unit virtual force at Δ; M^{θ}_{Vi} = virtual moment equation of segment i due to a unit virtual couple at θ; M_i = real bending moment equation in segment i due to the external loading; $\sum$ = summation over the members or segments; A = cross sectional area; I = moment of inertia; L = member length; and E = elastic modulus.

Remember, only one real analysis is required per structure, but a separate virtual load analysis must be conducted for the structure for each desired displacement or rotation.

Problems on Exam 1 will be similar to the homework problems. There will be three problems: truss, beam and frame. Each problem will ask multiple questions.