American University of Beirut
Faculty of Engineering & Architecture
Civil Engineering Department

EXAM [1] – SPRING 2014
(Tuesday, 18th March 2014)
CIVE410 – STRUCTURES II
CLOSED BOOK, 75 MINUTES

Name: SOLUTION **AUB-ID#:**

NOTES

- 3 PROBLEMS – 10 PAGES (INCLUDING THIS PAGE).
- READ PROBLEM STATEMENTS CAREFULLY.
- ASSUME ANY MISSING DATA YOU MAY REQUIRE. WRITE YOUR COMMENTS BELOW.
- ALL YOUR ANSWERS SHOULD BE PROVIDED ON THE QUESTION SHEETS.
- WELL ORGANIZED AND SYSTEMATIC SOLUTION WILL BE CREDITED. NEATNESS COUNTS.
- *TRY NOT* TO USE THE BACK OF THE SHEETS FOR ANSWERS UNLESS YOU RUN OUT OF SPACE.
- NOTE THE PERCENTAGE OF POINTS ASSIGNED FOR EACH PROBLEM.
- CHECK BOXES ARE FOR YOU TO CONFIRM YOU HAVE SOLVED A QUESTION ☑

YOUR COMMENT(S)

- -
- -

DO NOT WRITE IN THE SPACE BELOW

MY COMMENT(S)

- -
- -

YOUR GRADE

Problem [1]: ___ /20
Problem [2]: ___ /30
Problem [3]: ___ /50
Other: ___

Good Luck & Best Wishes
Prof. Hisham S. Basha

Problem [1]: *(20 points)*

Discuss ***Stability and Determinacy*** for the structures shown in the accompanying Figures.

Calculations and/or Diagrams:

[A] All reactions are concurrent at O → Geometrically Unstable.

∴ Structure is Unstable.

[B] $i = (3m + r) - (3j + h)$.

composite system.

$m = 15$, $r = 4$, $j = 8$, $h' = 20$ $\Rightarrow i = (45 + 4) - (24 + 20)$.

$= 49 - 44 = 5$

OR $i = (3m + r) - (3j + h) + (m' + r') - 2j'$

$m = 3$; $m' = 12$

$j = 4$; $j' = 4$

$r = 4$; $r' = 0$

$h = 0$

$\Rightarrow i = (9 + 4) - (12 + 0) + (12 + 0) - 8$

$= 13 - 12 + 4 = 5$

System is Stable & Statically indeterminate of the 5th degree.

[C] $m = 36$; $r = 9$; $j = 25$; $h = 11$

$i = (3m + r) - (3j + h) = (108 + 9) - (75 + 11)$

$= 117 - 86 = 31$

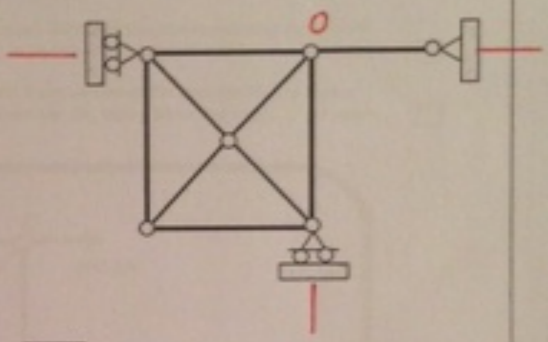
OR

$i = i_{ext} + i_{int} = 6 + (3 * 8 + 4 - 3)$

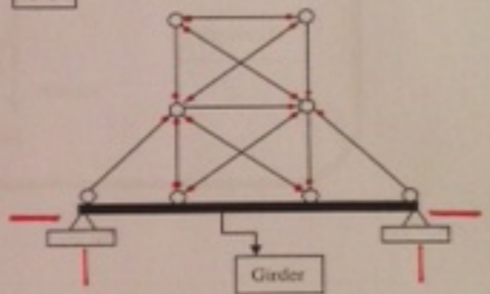
$= 6 + 25 = 31$

System is stable & Statically indet. to the 31st degree.

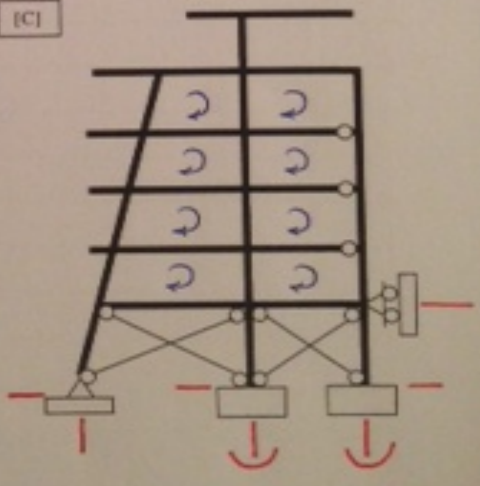
[A]



[B]



[C]



Problem [2]: *(30 points)*

The given truss **ABCD** is subjected to the shown loads (Figure 2). Knowing that the steel truss has the following properties:

The cross-sectional area of the diagonal member AC is equal to 900 mm² whereas all other members each have an area of 1200mm².

Use $\alpha = 1.08(10^{-5})/^{\circ}C$ *and* $E = 200$ *GPa* $(1GPa = 10^{6} kN/m^{2})$.

Solve the following:

[A] Determine the ***vertical*** displacement of joint ***C*** of the steel truss shown in the accompanying figure due to the given loads in addition to an increase of temperature in member ***AD*** only of 60°C. *(15 points)* ☐

[B] Determine the ***horizontal*** displacement of joint ***C*** of the steel truss shown in the accompanying figure due to the given loads in addition to a fabrication error in member ***DC*** being 5mm too long. *(15 points)* ☐

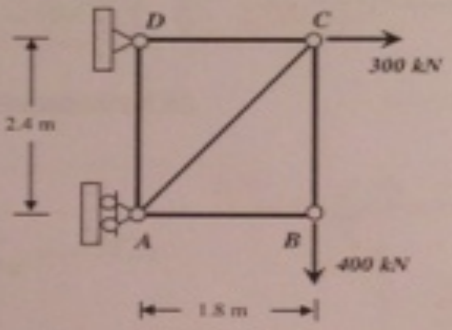
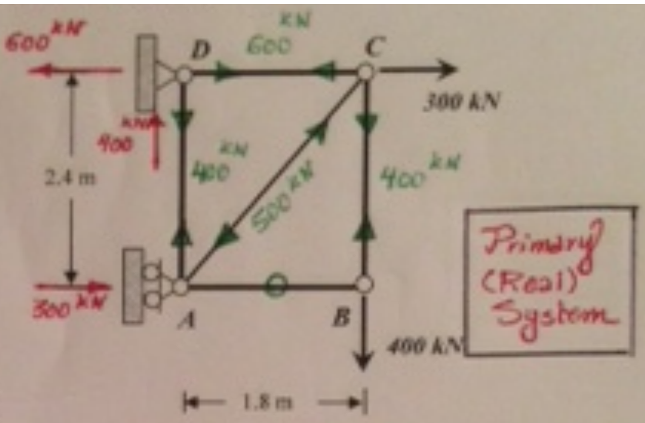


Figure (2)

Calculations and Diagrams:

Reactions:-

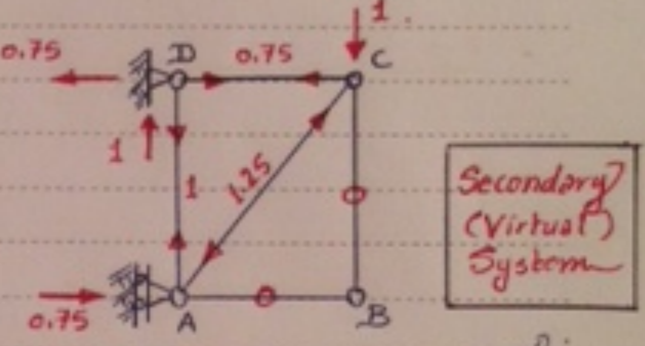
- $\Sigma M_D = 0 \Rightarrow \underline{X_A = 300^{kN}} \rightarrow$
- $\Sigma X = 0 \Rightarrow \underline{X_D = 600^{kN}} \leftarrow$
- $\Sigma Y = 0 \Rightarrow \underline{y_D = 400^{kN}} \uparrow$.



Calculations and Diagrams (cont'd):

P.V.W

$$\Sigma W_{ext} = \Sigma W_{int}$$



$$1 * \Delta = \sum_{i=1}^{n}\left(\frac{N_0 N_1 L}{EA}\right)_i + \sum_{i=1}^{n}(N_1 . \alpha . \Delta T . L)_i + \sum_{i=1}^{n}\cancelto{0}{(N_1 . \delta L_{Fab.})_i}.$$

$$1 * \Delta_{C_{Vert.}} = \overbrace{\frac{(0.75)(600)(1.8)}{200\times10^{6}\times1200\times10^{-6}}}^{(DC)} + \overbrace{\frac{(1)(400)(2.4)}{200\times10^{6}\times1200\times10^{-6}}}^{(AD)} + \overbrace{\frac{(1.25)(500)(3)}{200(10^{6})\times900\times10^{-6}}}^{(AC)} + \overbrace{(1)(1.08)(10^{-5}).(+60).(2.4)}^{(N_1 \alpha \Delta T . L)_{AD}}$$

$$\Rightarrow \Delta_{C_{Vert}} = 0.003375 + 0.004 + 0.010417 + 0.0015552.$$

$$= +0.019347 \ m.$$

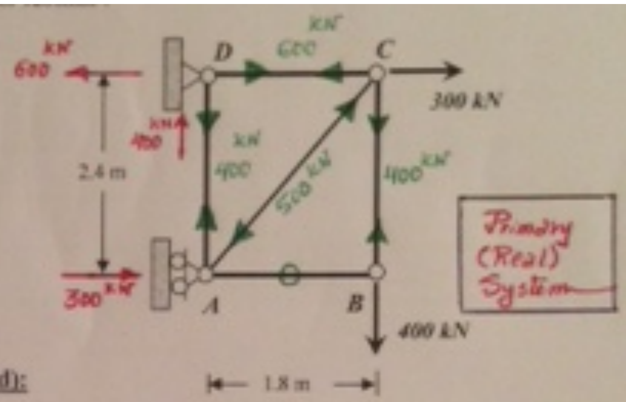
$$\Rightarrow \boxed{\Delta_{C_{Vert.}} = 19.35 \ mm \ (\downarrow)}.$$

Reactions :-

$\Sigma M_{/D} = 0 \Rightarrow \underline{X_A = 300^{kN}} \rightarrow$

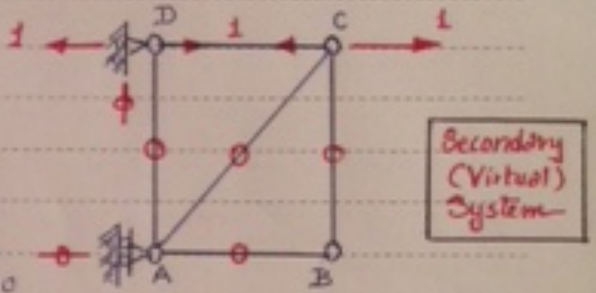
$\Sigma X = 0 \Rightarrow \underline{X_D = 600^{kN}} \leftarrow$

$\Sigma Y = 0 \Rightarrow \underline{Y_D = 400^{kN}} \uparrow$.



Calculations and Diagrams (cont'd):

P.V.W.



$\Sigma W_{ext} = \Sigma W_{int}$

$\Rightarrow 1 * \Delta = \sum_{i=1}^{n}\left(\frac{N_0 N_1 L}{EA}\right)_i +$

$\cancelto{0}{\sum_{i=1}^{n}(N_1.\alpha.\Delta T.L)_i} + \sum_{i=1}^{n}(N_1.\,SL_{Fab.})_i$.

$\Rightarrow 1 * \Delta_{c_{Horiz.}} = \frac{(600)(1) * 1.8^m}{(EA)_{DC}} + 0 + (1)(+0.005^m)$.

$\Rightarrow \Delta_{c_{Horiz.}} = \frac{(600)(1.8)}{200\times\cancel{10^6}\times 1200\times\cancel{10^{-6}}} + 0.005^m = +0.0095^m$.

$\Rightarrow \boxed{\Delta_{c_{Horiz.}} = 9.5\ mm \rightarrow}$

Problem [3]: *(50 points)*

The frame ***ABCDE*** shown in the accompanying figure (Figure 3) has a hinged support at *A* and roller support at *B*, as shown. Knowing that the horizontal beam ***CDE*** has a moment of inertia ***(2I)*** whereas ***AC*** and ***BD*** have moments of inertias of ***(I)***. Neglect axial and shear deformation.

Solve in terms of ***(EI)*** the following:

[A] Using the Energy Method (Virtual Work Concept), determine:

- The vertical displacement δ_E *(20 points)* ☐
- The slope θ_A at *A*. *(15 points)* ☐

[B] If an external moment M_A is applied to restrain support *A* from rotation. Compute by using the Energy Method (Virtual Work Concept), the value and direction of the restraining moment. *(15 points)* ☐

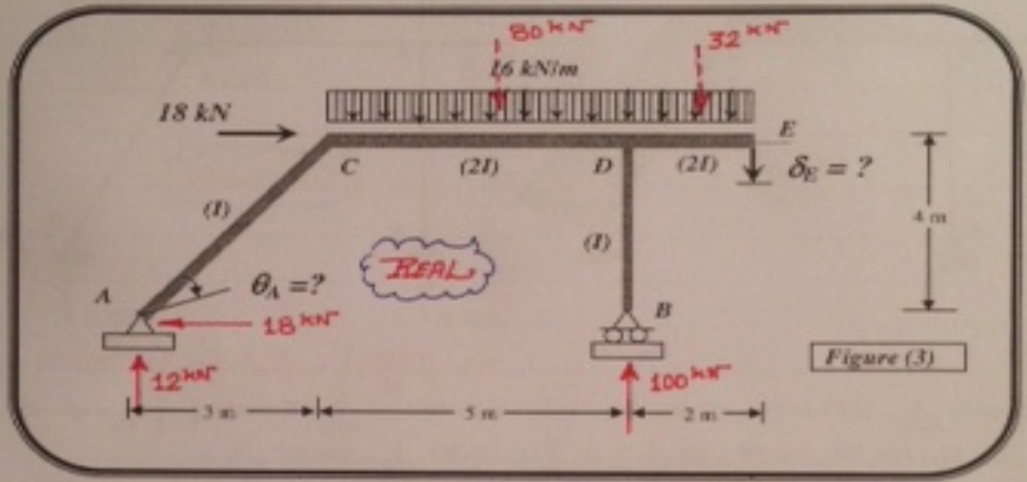
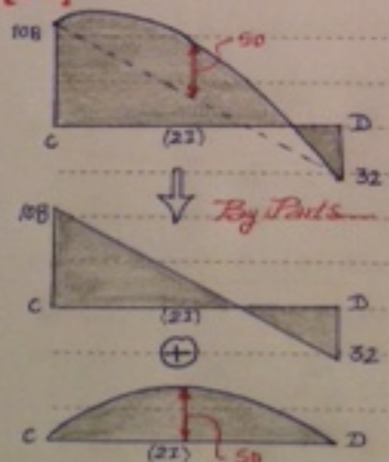
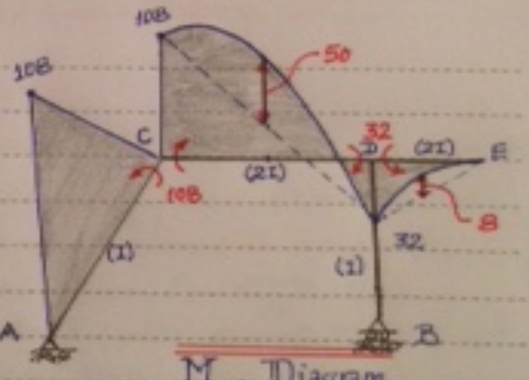


Figure (3)

Calculations and Diagrams :

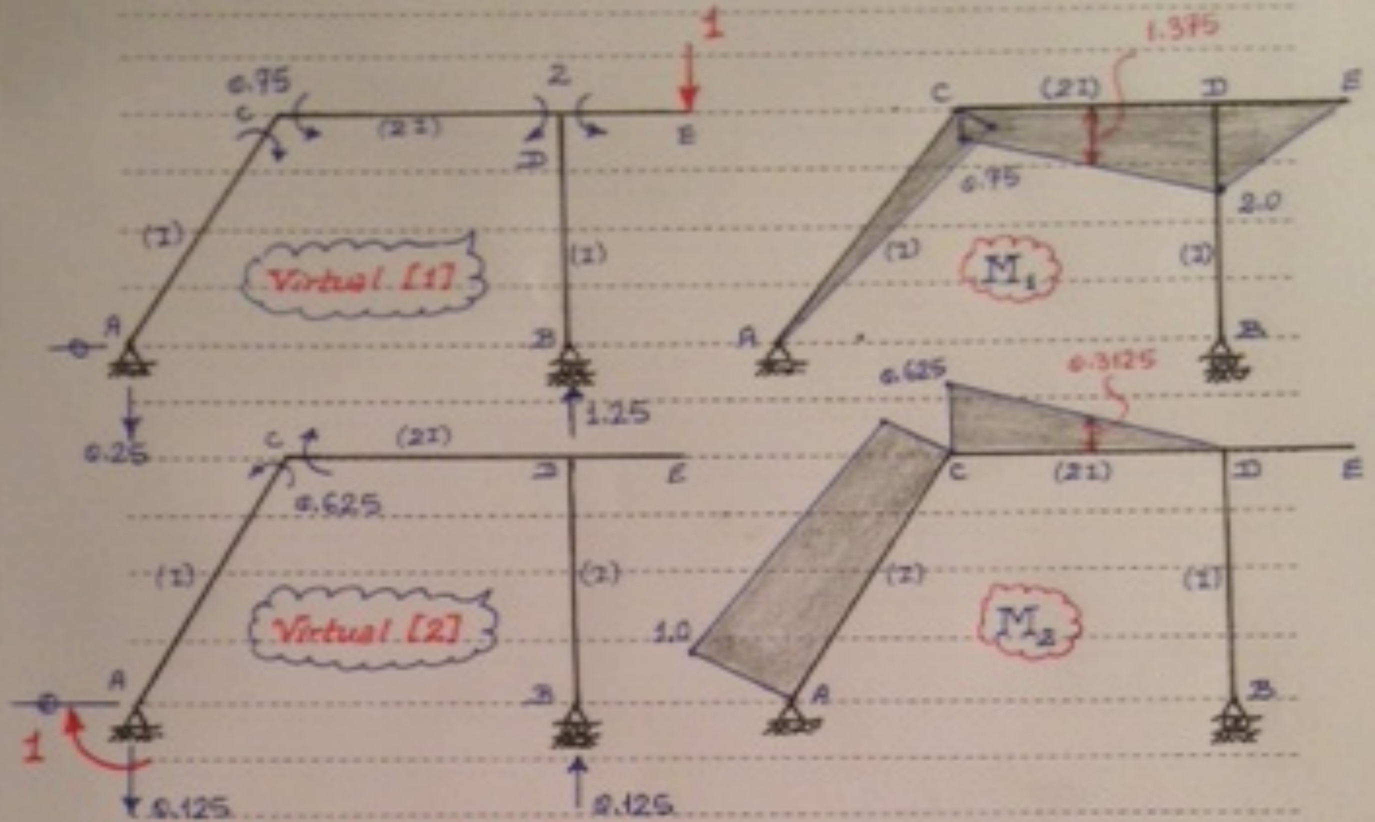
[A]





M_o – Diagram

Calculations and Diagrams (cont'd):



❀ P.V.W [1] ⇒ $1 * \delta_E = \int \frac{M_o M_1}{EI} dx$

⇒ $\delta_E = \frac{1}{EI}\Big\{-\frac{5}{3}(108)(0.75) + \frac{5}{2\times6}\big[-2(108)(0.75) + 2(32)(2) - 108(2) + 52(0.75)\big] - \frac{2}{2\times3}(6\times50)(1.375)$

$+ \frac{2}{2\times3}(32)(2) - \frac{2}{3\times2}(8\times2)(1)\Big\} = \frac{1}{EI}\Big\{-135 - 94.167 - 114.583 + 21.333 - 5.333\Big\}$

⇒ $\delta_E = -\frac{327.75}{EI}$ (↑) (-ve indicates opp. to assumed dummy load)

❀ P.V.W [2] ⇒ $1 * \theta_A = \int \frac{M_o M_2}{EI} dx$

⇒ $\theta_A = \frac{1}{EI}\Big\{\frac{5}{6}\big[0 + 2(108)(0.625) + 1(108) + 0\big] + \frac{5}{2\times6}\big[2(108)(0.625) + 0 + 0 - 32(0.625)\big]$

$+ \frac{2}{3\times2}(50\times5)(0.3125)\Big\} = \frac{1}{EI}\Big\{202.5 + 47.917 + 26.0417\Big\}$

⇒ $\theta_A = \frac{276.46}{EI}$ (CW) (+ve indicates in the direction of the dummy moment)

❀ [B] From part [A] ⇒ $\theta_A = \frac{276.46}{EI}$ (CW)

It is required to determine the value of applied moment M_A that will restrain support A ; i.e. M_A will cause $\frac{276.46}{EI}$ (CCW) for compatibility.

⇒ $\boxed{f_{20} + M_A * f_{22} = 0}$ ⇒ $M_A = -\frac{f_{20}}{f_{22}}$; knowing that $f_{20} = \int \frac{M_o M_2}{EI} dx = \frac{276.46}{EI}$

and $f_{22} = \int \frac{M_2 M_2}{EI} dx = \frac{5}{6EI}\big[2(1)(1) + 2(0.625)^2 + 1(0.625) + 0.625(1)\big] + \frac{5}{3\times2EI}(0.625\times0.625)$

$= \frac{1}{EI}(3.36 + 0.325) = \frac{3.686}{EI}$ (CW) ⟶ $M_A = -\frac{276.46}{3.686} = -75$ ccw

∴ Restraining Moment $M_A = 75^{\text{kN.m}}$ (CCW)