

## 算例 1-001

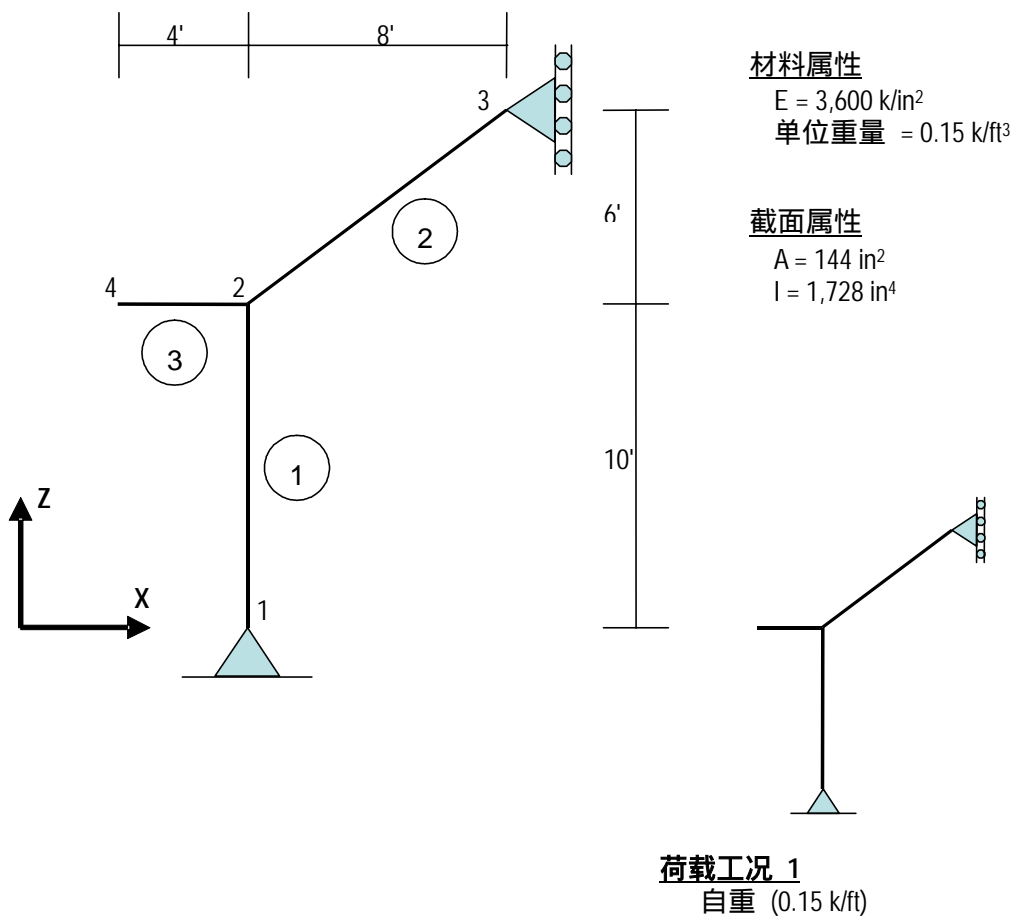
### 框架 – 一般荷载

#### 算例描述

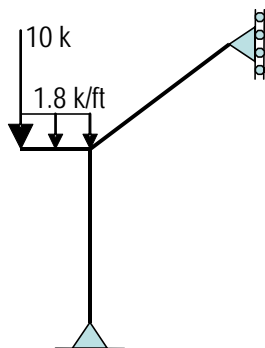
对一个三单元框架施加了包含不同类型分布和/或集中荷载的七种荷载工况。将指定节点处得到的位移与手算结果进行了比较。

**重要提示：**分析中只考虑了弯曲变形。在 SAP2000 中，通过将面积属性修正参数设为 1000，并将剪切属性修正系数设置为 0 实现这一点。

#### 几何特性、属性和荷载

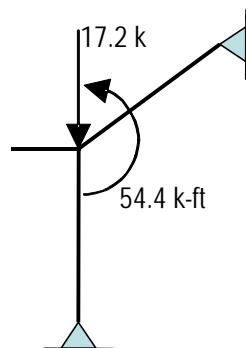


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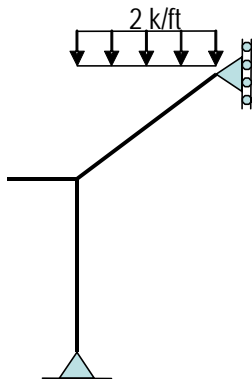
## 荷载工况 2

在框架单元 3 上的整体均部荷载，  
及在节点 4 的集中荷载。



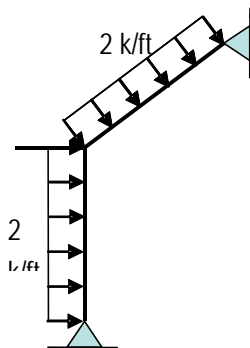
## 荷载工况 3

在节点 2 的整体节点力和弯矩



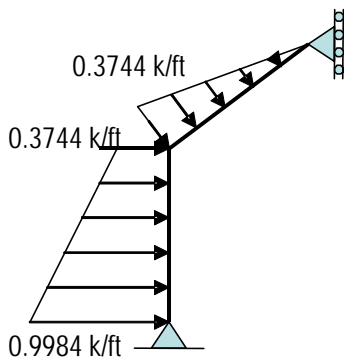
## 荷载工况 4

在框架单元 2 的均部投影荷载



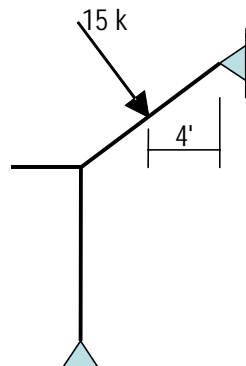
## 荷载工况 5

在框架单元 1 和 2 的局部方向的均部荷载



## 荷载工况 6

在框架单元 1 和 2 局部方向的  
梯形荷载



## 荷载工况 7

在框架单元 2 局部方向的集中荷载

**所测试的 SAP2000 技术要点：**

- 自重的施加与计算
- 竖向均布荷载的施加与计算
- 全局坐标系中均布荷载的施加
- 框架局部坐标系中局部荷载的施加
- 框架单元上梯形和三角形荷载的施加
- 节点弯矩和力的施加
- 所有类型荷载作用的静力分析

**结果比较**

采用 Cook and Young 1985 一书第 244 页的单位力法手算得出独立结果。

荷载 工况	输出参数	SAP2000	独立结果	差值百分比
1	$U_z$ (节点 3) (in)	-0.02639	-0.02639	0%
2	$U_z$ (节点 3) (in)	0.06296	0.06296	0%
3	$U_z$ (节点 3) (in)	0.06296	0.06296	0%
4	$U_z$ (节点 3) (in)	-0.29630	-0.29630	0%
5	$U_x$ (节点 2) (in)	0.31250	0.31250	0%
6	$U_x$ (节点 2) (in)	0.11556	0.11556	0%
7	$U_x$ (节点 2) (in)	0.00651	0.00651	0%

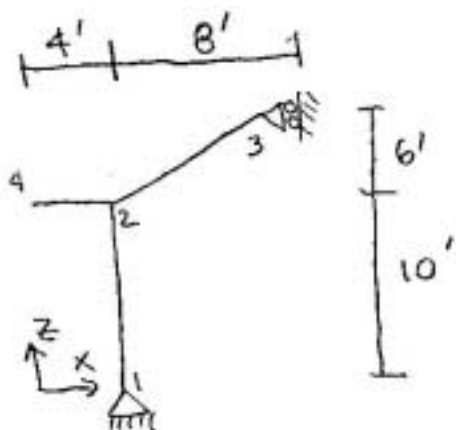
计算模型文件: 算例 1-001

**结论**

SAP2000 的结果和独立计算的结果精确吻合。

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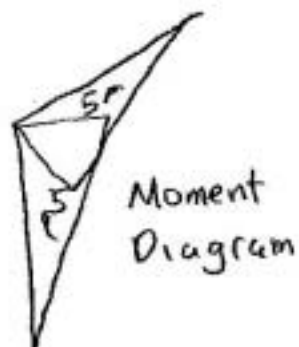
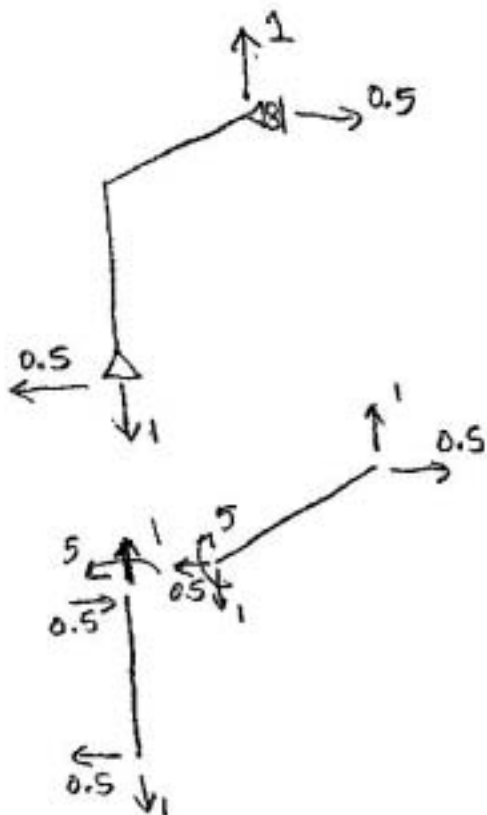
## 手算过程



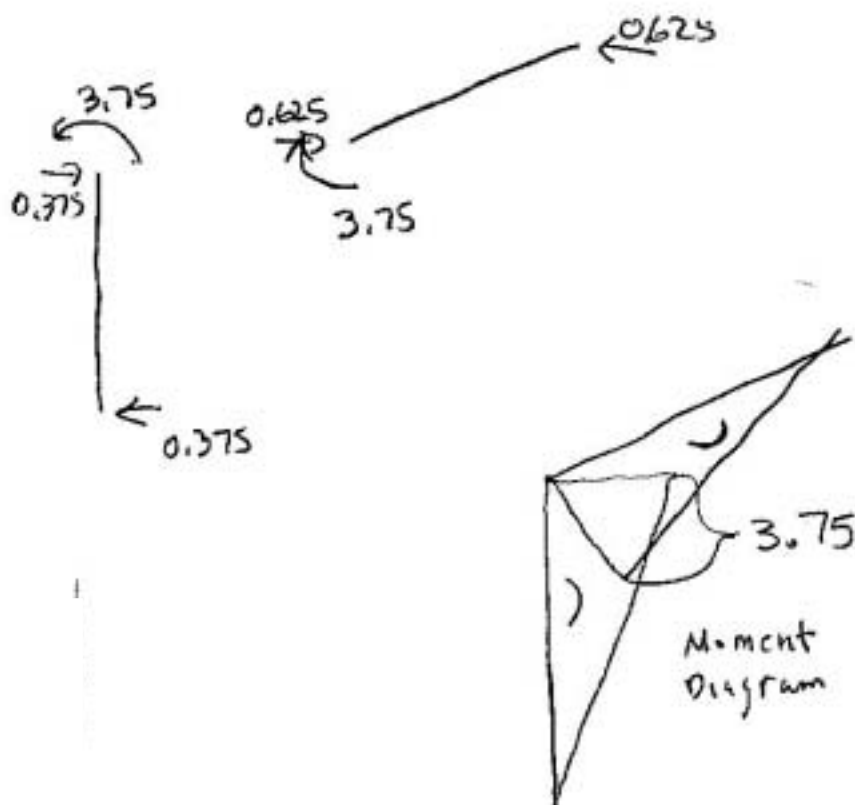
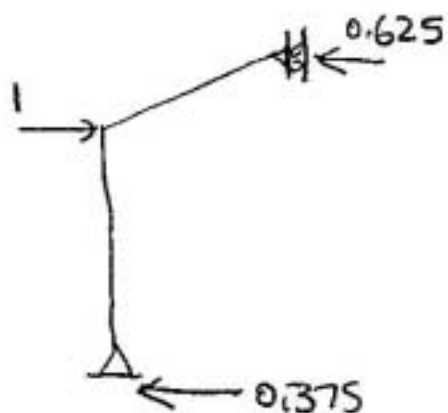
Evaluate using

$$\int \frac{Mm}{EI}$$

Virtual Load at Joint 3 in z direction

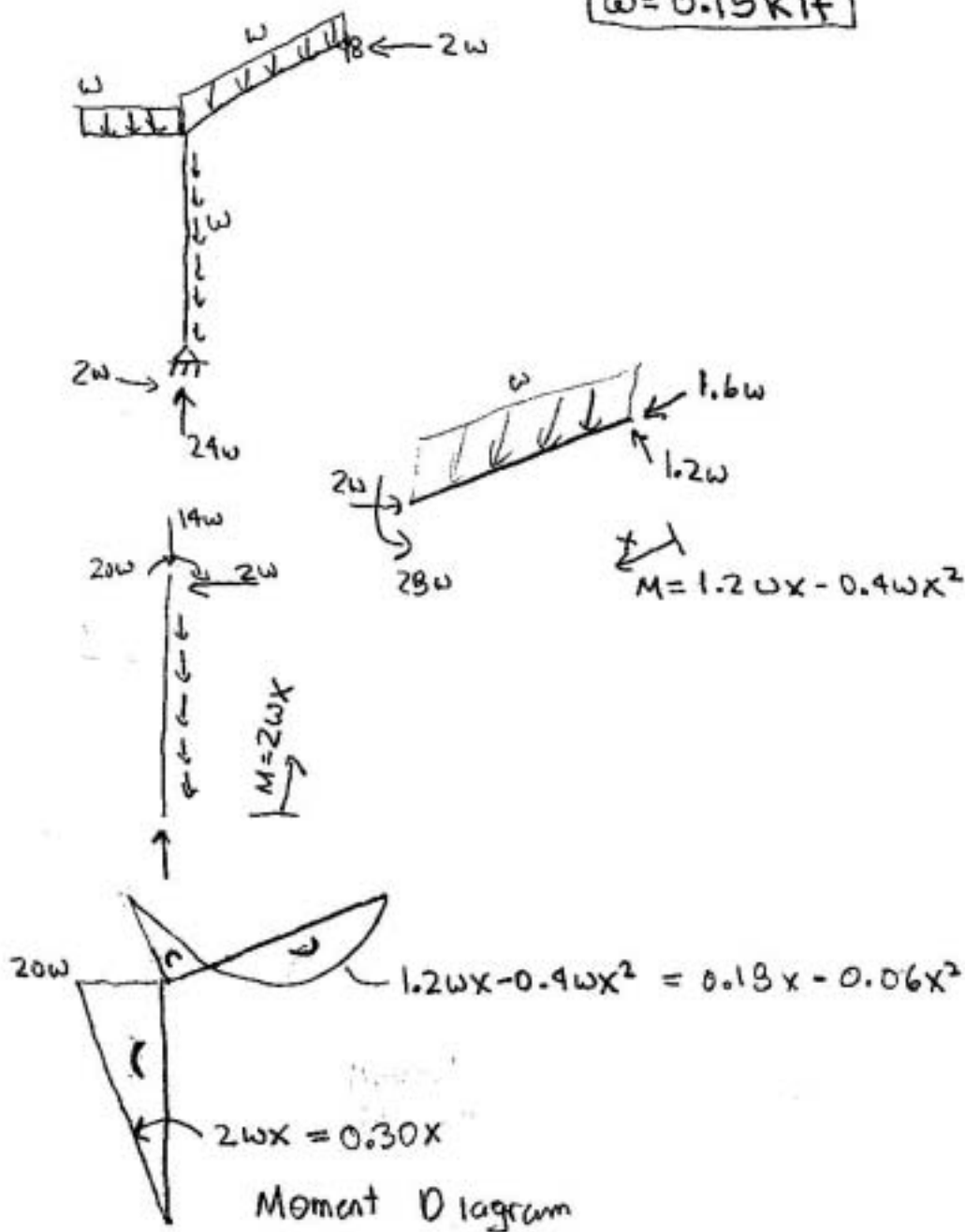


## Virtual Load at Joint 2 in X Direction



## Load Case 1

$w = 0.15 \text{ Klf}$



Load Case 1

$$\Delta EI = -\int_0^{10} 0.15x^2 dx + \int_0^{10} (0.09x^2 - 0.03x^3) dx$$

$$= -\frac{0.15x^3}{3} \Big|_0^{10} + \frac{0.09x^3}{3} \Big|_0^{10} - \frac{0.03x^4}{4} \Big|_0^{10}$$

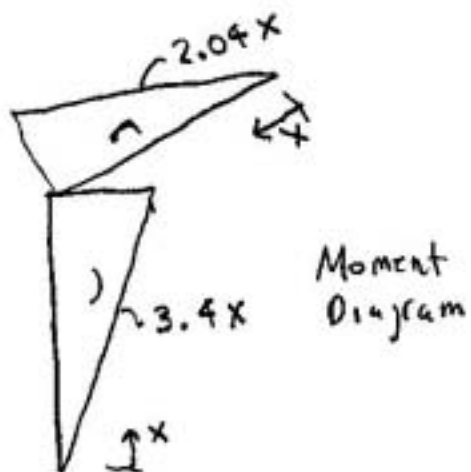
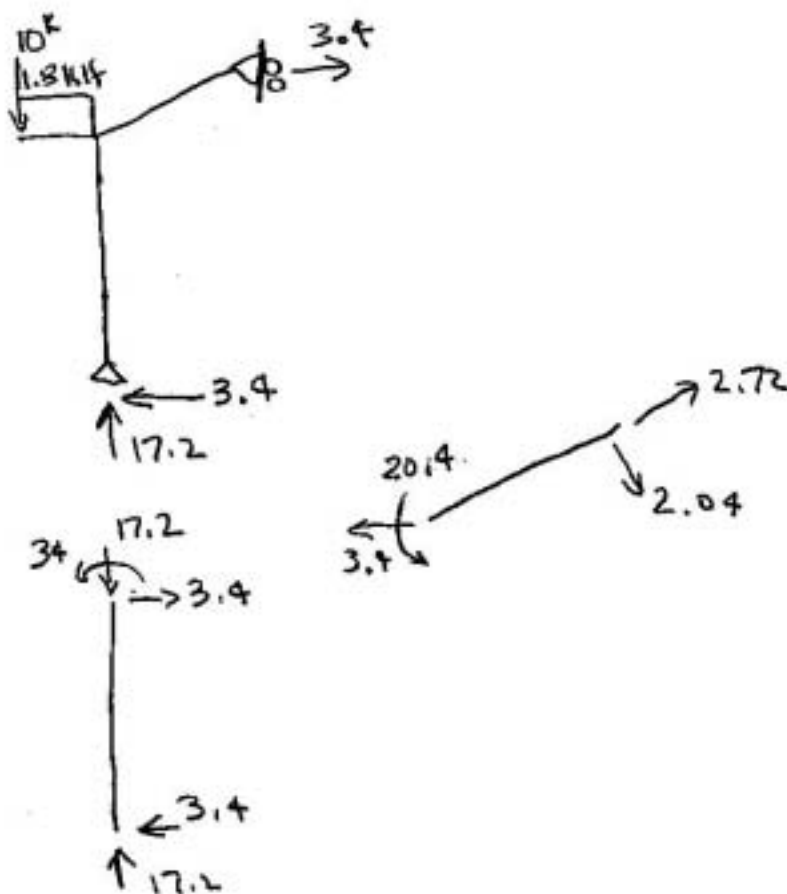
$$= -50 + 30 - 75$$

$$\Delta EI = -95 \text{ k-ft}^3$$

$$\Delta = \frac{-95}{EI} = \left( -95 \text{ k-ft}^3 \right) \left( \frac{1 \text{ in}^2}{3600 \text{ k}} \right) \left( \frac{1}{1728 \text{ in}^4} \right) \left( \frac{1728 \text{ in}^3}{1 \text{ ft}^3} \right)$$

$$\boxed{\Delta = -0.02639}$$

## Load Case 2





Load Case 2

$$\begin{aligned}\Delta EI &= \int_0^{10} 1.7x^2 dx - \int_0^{10} 1.02x^2 dx \\ &= \left. \frac{1.7x^3}{3} \right|_0^{10} - \left. \frac{1.02x^3}{3} \right|_0^{10} \\ &= \frac{1700}{3} - \frac{1020}{3}\end{aligned}$$

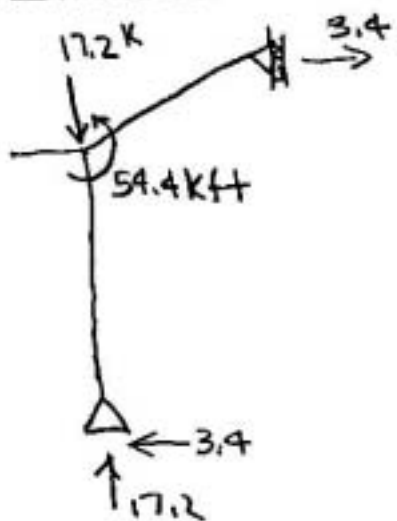
$$\Delta EI = \frac{680}{3} \text{ K ft}^3$$

$$\Delta = \frac{680}{3EI} = \left( \frac{680 \text{ K ft}^3}{3} \right) \left( \frac{1 \text{ in}^2}{3600 \text{ K}} \right) \left( \frac{1}{1728 \text{ in}^4} \right) \left( \frac{1728 \text{ in}^3}{1 \text{ ft}^3} \right)$$

$$\Delta = 0.06296 \text{ in}$$

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Load Case 3

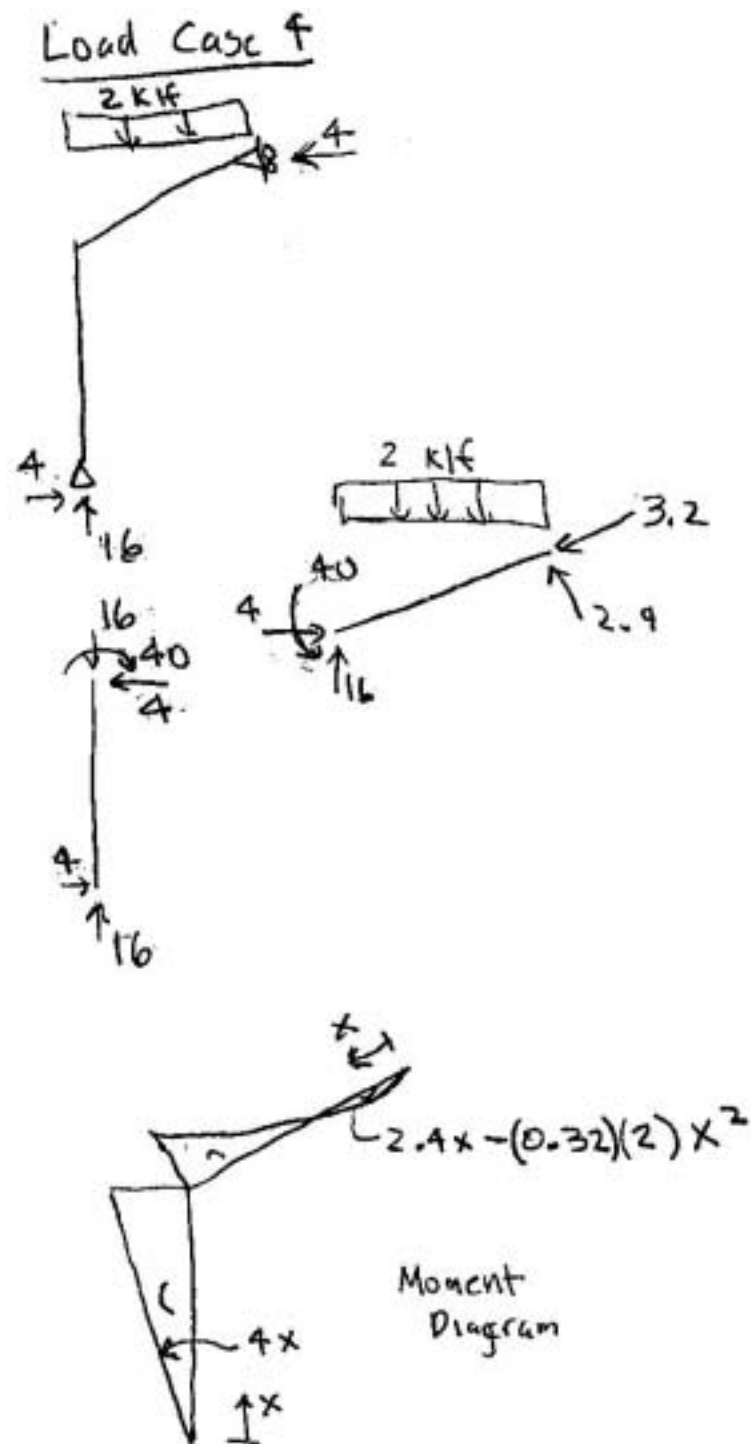


Same as Load Case 2

$$\Delta = 0.06296 \text{ in}$$

# Software Verification

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Load Case 4

$$\begin{aligned}\Delta EI &= -\int_0^{10} 2x^2 dx + \int_0^{10} (1.2x^2 - 0.32x^3) \\ &= -\frac{2x^3}{3} \Big|_0^{10} + \frac{1.2x^3}{3} \Big|_0^{10} - \frac{0.32x^4}{4} \Big|_0^{10} \\ &= -\frac{2000}{3} + \frac{1200}{3} - \frac{3200}{4}\end{aligned}$$

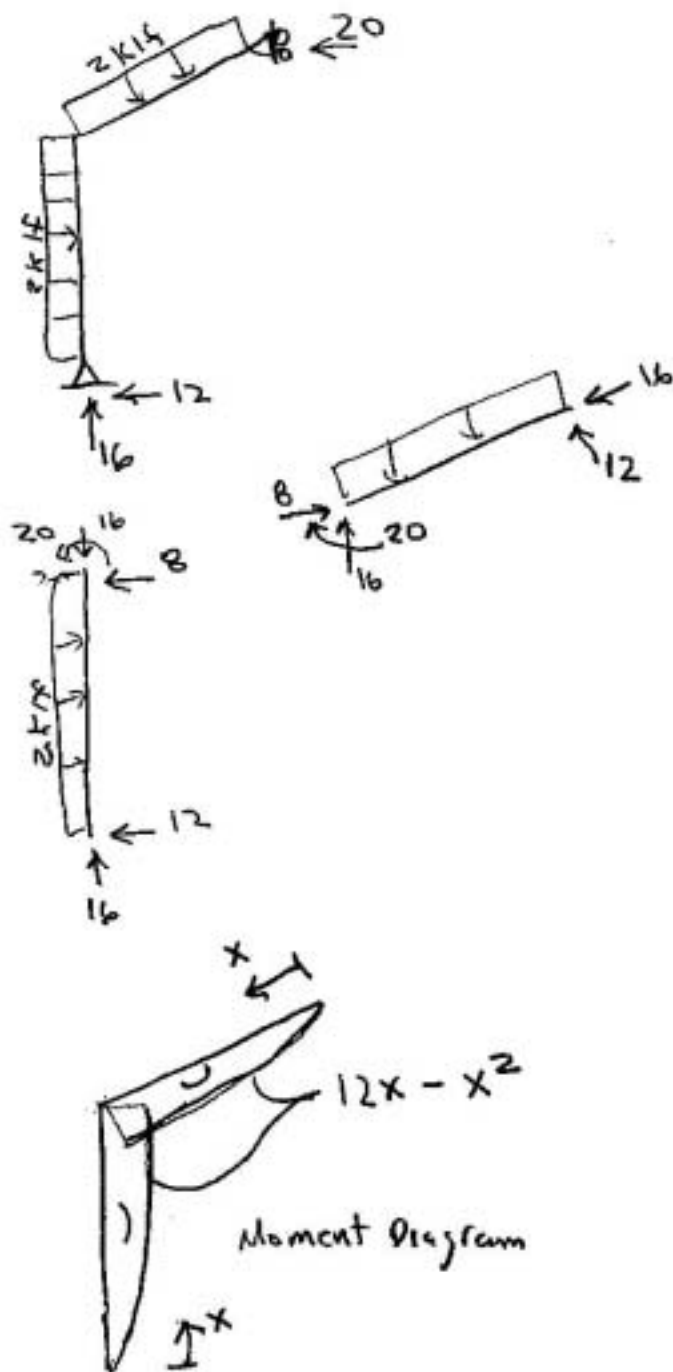
$$\Delta EI = -\frac{3200}{3} \text{ K ft}^3$$

$$\Delta = \frac{-3200}{3EI} = \left( \frac{-3200 \text{ K ft}^3}{3} \right) \left( \frac{1 \text{ in}^2}{3600 \text{ K}} \right) \left( \frac{1}{1728 \text{ in}^4} \right) \left( \frac{1728 \text{ in}^3}{1 \text{ ft}^3} \right)$$

$$\Delta = -0.29630 \text{ in}$$

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## Load Case 5



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Load Case 5

$$\Delta EI = 2 \times 0.375 \int_0^{10} (12x^2 - x^3) dx$$

$$= 0.75 \left[ \frac{12x^3}{3} \Big|_0^{10} - \frac{x^4}{4} \Big|_0^{10} \right]$$

$$= 0.75 [4000 - 2500]$$

$$\Delta EI = 1125 \text{ K-ft}^3$$

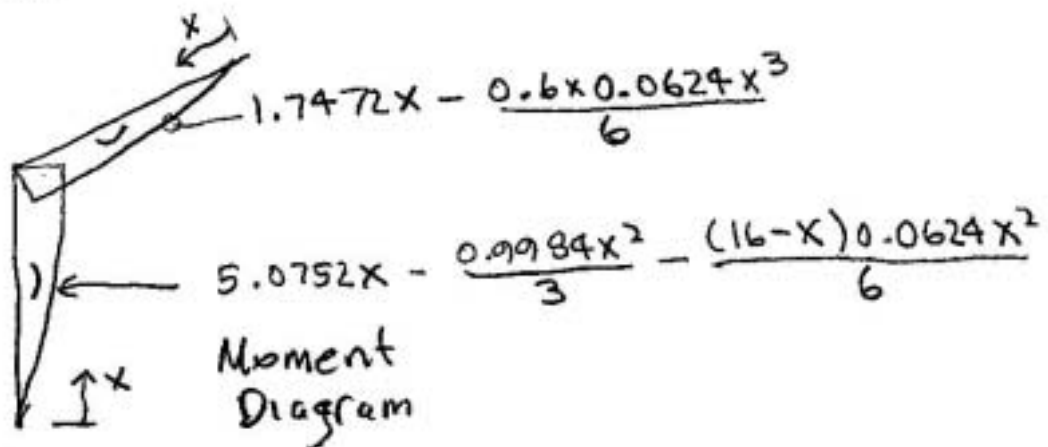
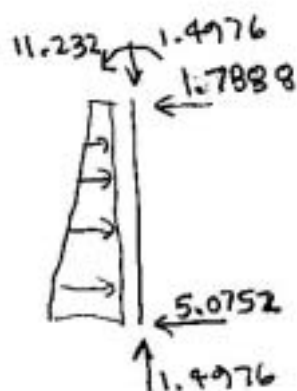
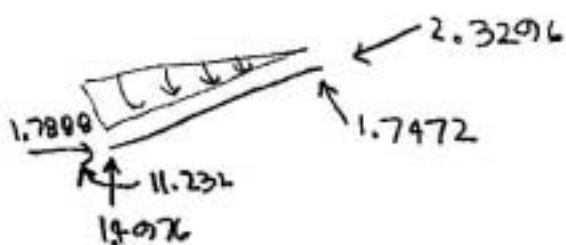
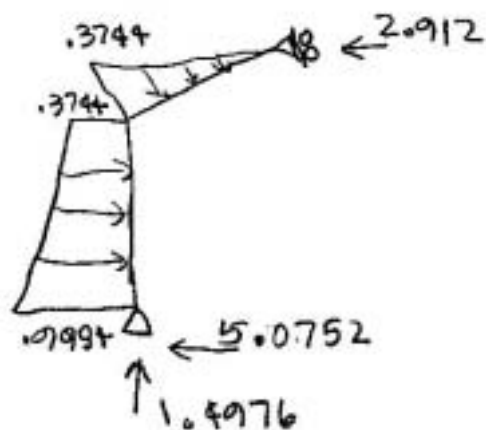
$$\Delta = \frac{1125}{EI} = (1125 \text{ K-ft}^3) \left( \frac{1 \text{ in}^2}{3600 \text{ K}} \right) \left( \frac{1}{1728 \text{ in}^4} \right) \left( \frac{1728 \text{ in}^3}{1 \text{ ft}^3} \right)$$

$$\Delta = 0.31250 \text{ in}$$

# Software Verification

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## Load Case 6



Load Case 6

$$\begin{aligned}\Delta EI &= 0.375 \left[ \int_0^{10} \left( 1.7472x^2 - \frac{0.6 \times 0.0624x^4}{6} + 5.0752x^2 - \frac{0.9784x^3}{3} \right. \right. \\ &\quad \left. \left. - \frac{(16-x)0.0624x^3}{6} \right) dx \right] \\ &= 0.375 \left[ \left( \frac{6.8224x^3}{3} - \frac{2.0952x^4}{24} + \frac{0.02496x^5}{30} \right) \right]_0^{10} \\ &= 0.375 \left[ \frac{6822.4}{3} - \frac{20952}{24} + \frac{2496}{30} \right]\end{aligned}$$

$$\Delta EI = 416 \text{ K-ft}^3$$

$$\Delta = \frac{416}{EI} = (416 \text{ K-ft}^3) \left( \frac{1 \text{ in}^2}{3600 \text{ K}} \right) \left( \frac{1}{1728 \text{ in}^4} \right) \left( \frac{1728 \text{ in}^3}{1 \text{ ft}^3} \right)$$

$$\Delta = 0.11556 \text{ in}$$



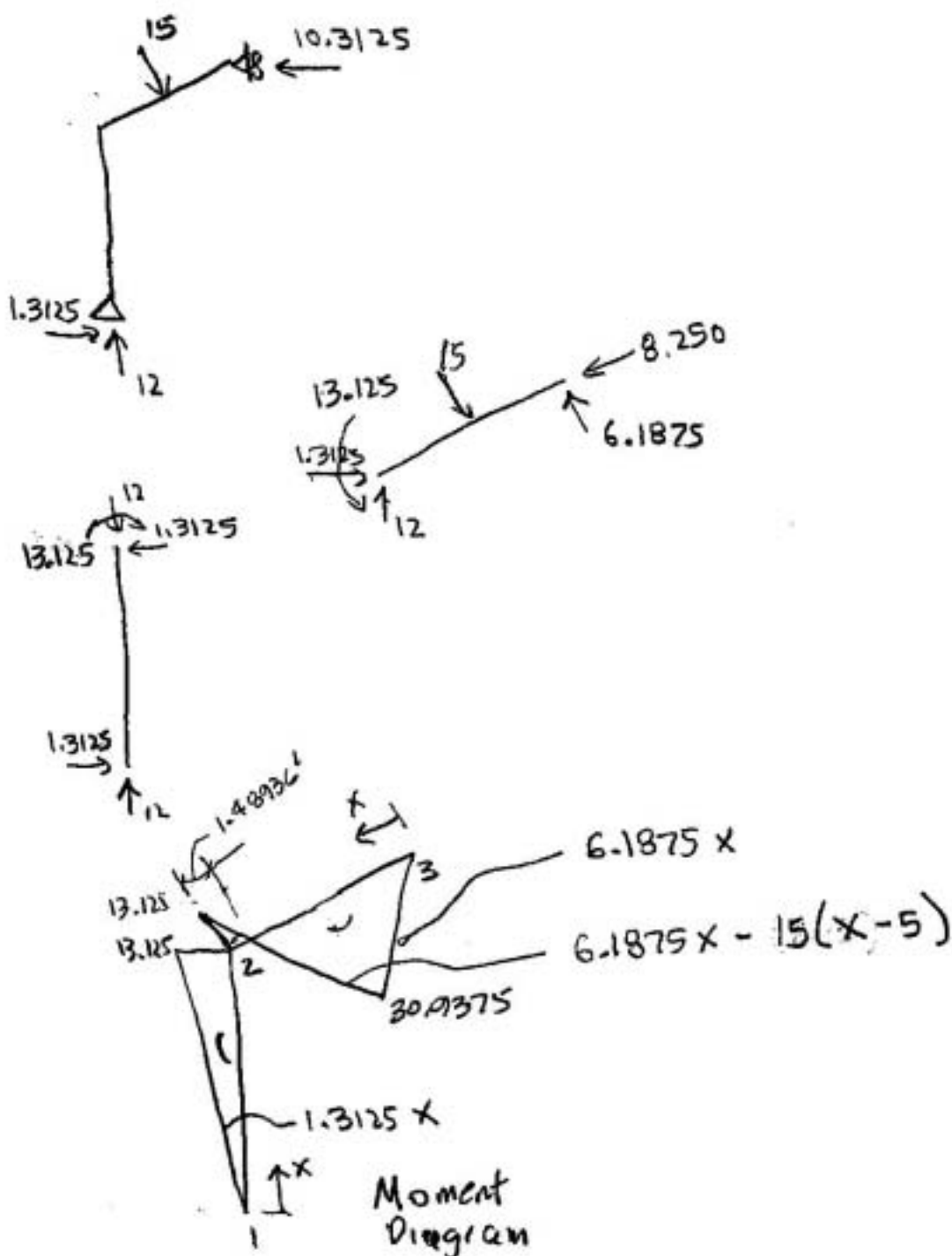
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### Load Case 7



Load Case 7

$$\Delta EI = 0.375 \left[ -\int_0^{10} 1.3125 x^2 dx + \int_0^5 6.1875 x^2 dx + \int_5^{10} (-8.8125 x^2 + 75x) dx \right]$$

$$\Delta EI = 0.375 \left[ -\frac{1.3125 x^3}{3} \Big|_0^{10} + \frac{6.1875 x^3}{3} \Big|_0^5 + \frac{-8.8125 x^3}{3} \Big|_5^{10} + \frac{75 x^2}{2} \Big|_5^{10} \right]$$

$$\Delta EI = 0.375 \left[ \frac{-1312.5}{3} + \frac{773.4375}{3} - \frac{8812.5}{3} + \frac{1101.5625}{3} + 3750 - 937.5 \right]$$

$$\Delta EI = 0.375(62.5)$$

$$\Delta EI = 23.4375 \text{ K ft}^3$$

$$\Delta = \frac{23.4375}{EI} = \left( 23.4375 \text{ K ft}^3 \right) \left( \frac{1 \text{ in}^2}{3600 \text{ K}} \right) \left( \frac{1}{1728 \text{ in}^4} \right) \left( \frac{1728 \text{ in}^3}{1 \text{ ft}^3} \right)$$

$$\Delta = 0.00651 \text{ in}$$