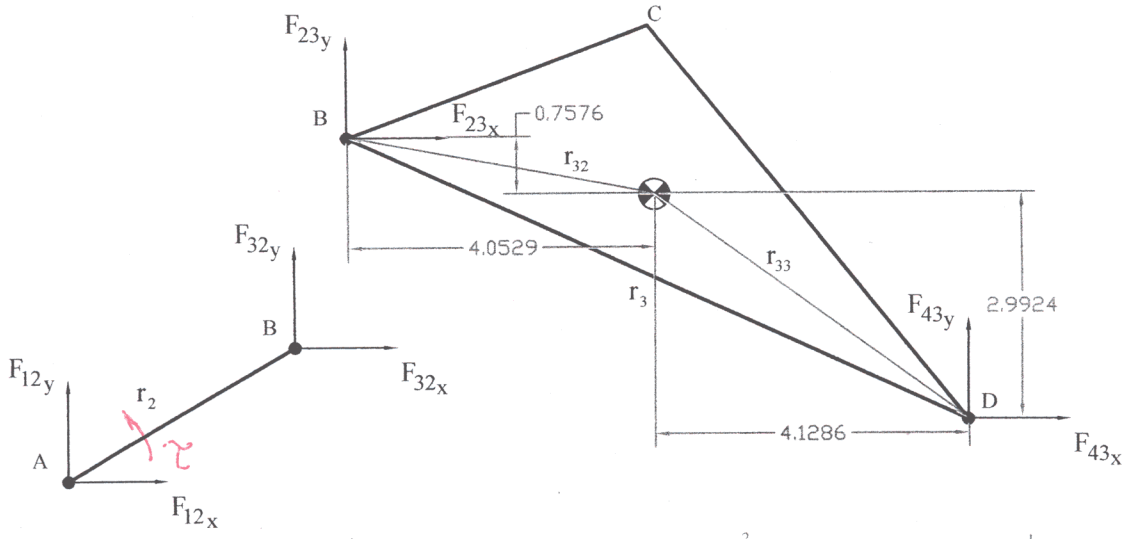
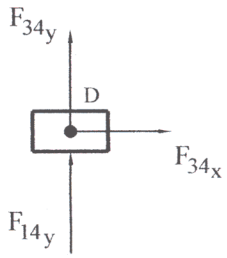
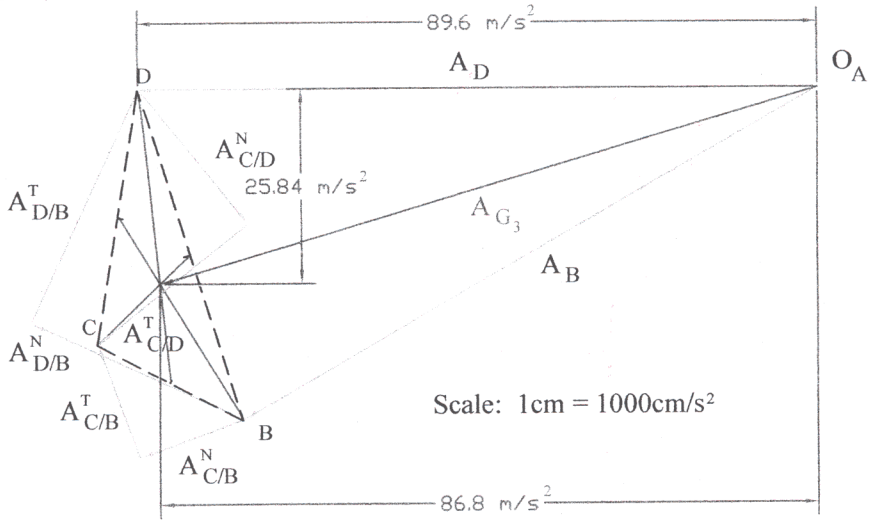
Example 4.10 Consider the slider-crank mechanism of examples 4.8 and 4.9. Determine the required torque τ_2 using the matrix method.







Member Two

$\Sigma F_{2x} = m_2 a_{G2x} \rightarrow$ $\boxed{F_{12x} - F_{23x} = 0}$ or $F_{12x} = F_{23x}$

$\Sigma F_{2y} = m_2 a_{G2y} \rightarrow$ $\boxed{F_{12y} - F_{23y} = 0}$ $F_{12y} = F_{23y}$

$\Sigma M_{G_2} = I_{G_2} \ddot{\theta}_2 \rightarrow -F_{32x}\frac{r_{2y}}{2} + F_{32y}\frac{r_{2x}}{2} - F_{12y}\frac{r_{2x}}{2} + F_{12x}\frac{r_{2y}}{2} + \tau = 0$

$\boxed{F_{23x} r_{2y} - F_{23y} r_{2x} + \tau = 0}$

Member Three

$$\sum F_{3x} = m_3 a_{G3x} \qquad F_{23x} - F_{34x} = m_3 a_{G3x}$$

$$\sum F_{3y} = m_3 a_{G3y} \qquad F_{23y} - F_{34y} = m_3 a_{G3y}$$

$$\sum M_{G3} = I_{G3} \ddot{\theta}_3 \qquad -F_{23x} r_{32y} + F_{23y} r_{32x} - F_{34y} r_{33x} + F_{34x} r_{33y} = I_{G3} \ddot{\theta}_3$$

Member Four

$$\sum F_{4x} = m_4 a_{G4x} \qquad F_{34x} = m_4 a_{G4}$$

$$\sum F_{4y} = m_4 a_{G4y} \qquad F_{14y} + F_{34y} = 0$$

$$\begin{bmatrix} 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & r_{2y} & -r_{2x} & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 \\ 0 & 0 & -r_{32y} & r_{32x} & r_{33y} & -r_{33x} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} F_{12x} \\ F_{12y} \\ F_{23x} \\ F_{23y} \\ F_{34x} \\ F_{34y} \\ F_{14y} \\ \tau \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ m_3 a_{G3x} \\ m_3 a_{G3y} \\ I_{G3} \ddot{\theta}_3 \\ m_4 a_{G4x} \\ 0 \end{bmatrix}$$

$$A \quad x = b$$

$r_{2x} = r_2 \cos(30) = 0.0303\,m$

$r_{2y} = r_2 \sin(30) = 0.0175\,m$

$r_{32x} = -0.04053\,m$

$r_{32y} = 0.007576\,m$

$r_{33x} = 0.0413\,m$

$r_{33y} = -0.03\,m$

$a_{G4x} = -89\ m/s^2$

$a_{G3x} = -86.8\ m/s^2$

$a_{G3y} = -25.8\ m/s^2$

$m_3 = 0.3\,kg$

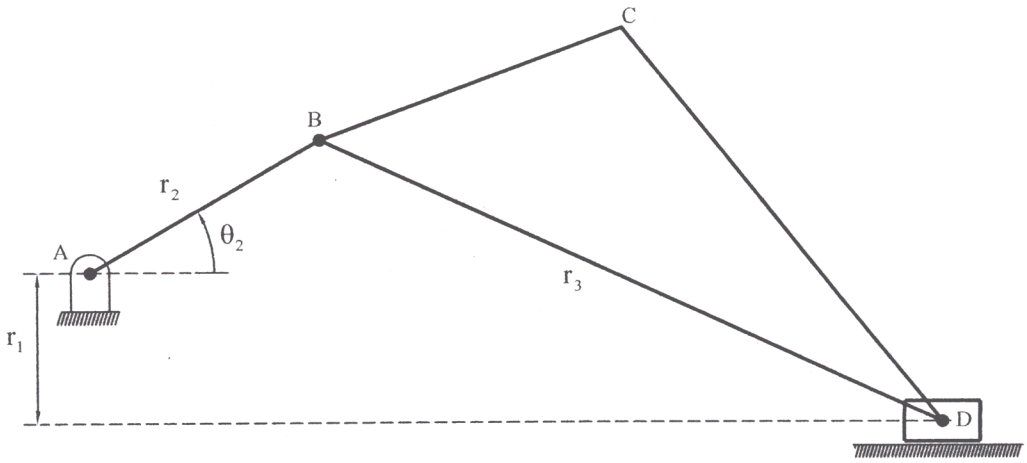
$m_4 = 0.15\,kg$

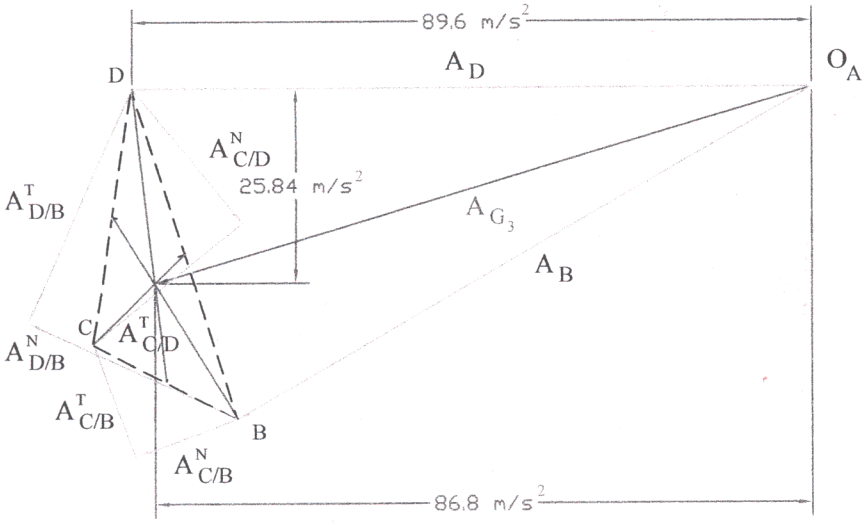
$I_{G3} = 2.5 \times 10^{-3}\,kg m^2$

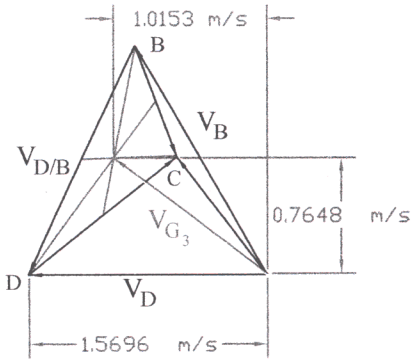
from $X = A^{-1} b \Rightarrow$

$$\begin{bmatrix} F_{12x} \\ F_{12y} \\ F_{23x} \\ F_{23y} \\ F_{34x} \\ F_{34y} \\ F_{14y} \\ \tau \end{bmatrix} = \begin{bmatrix} -39.385 \\ -6.933 \\ -39.385 \\ -6.933 \\ -13.35 \\ 0.82 \\ -0.82 \\ 0.4791 \end{bmatrix}$$

Example 4.11 Consider the slider-crank mechanism of examples 4.8 - 4.10. Determine the required torque τ_2 using the virtual work method. From previous examples, $\dot{\theta}_3 = -18.5$ rad/s and $\ddot{\theta}_3 = 378$ rad/s^2







$$\bar{F}_{IN_3} = -m_3 \bar{a}_{G_3} = -0.3(-86.8\,i - 25.84\,j) = 26.03\,i + 7.753\,j$$

$$\bar{V}_{G3} \cdot \bar{F}_{IN_3} + \bar{V}_{G4} \cdot \bar{F}_{IN_4} + \dot{\theta}_3 \cdot M_{IN_3} + \dot{\theta}_2 \tau = 0$$

$$\tau = \frac{(-1.0153\,i + 0.7648\,j) \cdot (26.03\,i + 7.753\,j) + (-1.57)(13.35) + (-18.5)(-0.945)}{-50} =$$

$$= 0.479\ \text{N·m}$$