10.1 Determine the magnitude and location of the equivalent offset inertial force for the connecting rod, link 2, of the slider-crank mechanism of Figure P10.1 for the position shown. The crank has a constant angular velocity of 100 rad/s counterclockwise. The mass of the connecting rod is 0.2 kg, and the moment of inertia about the center of mass, $G_2$, is 300 kg·mm$^2$.

![Figure P10.1](image)

10.2 For the mechanism of Problem 10.1, determine the crank torque $T_1$ required for dynamic equilibrium at the position shown. Neglect external loads and the inertia of crank 1 and slider 3.

10.3 For the mechanism of Problems 10.1 and 10.2, determine the crank torque $T_1$ required for dynamic equilibrium if slider 3 has a mass of 0.3 kg. Neglect external loads and the inertia of crank 1.

10.4 Determine the magnitude and location of the equivalent offset inertial force for the coupler link 2 of the slider-crank mechanism at the position shown in Figure P10.2. The crank has a constant angular velocity of 60 rev/min clockwise. The mass of the coupler is 500 kg, and the moment of inertia about the center of mass, $G_2$, is 100 kg m$^2$.

![Figure P10.2](image)

10.5 The four-bar linkage of Figure P10.3 has a constant crank angular velocity $\omega_1 = 60$ rad/s clockwise. Coupler link 2 has a mass of 0.3 kg and a moment of inertia about the center of mass, $G_2$, of 1000 kg·mm$^2$. Follower link 3 has a mass of 0.2 kg and a moment of inertia
about its center of mass, $G_3$, of 150 kg $\cdot$ mm$^2$. For the position shown, determine the following:

(a) The equivalent offset inertial force for the coupler.
(b) The equivalent offset inertial force for the follower.
(c) The crank torque $T_1$ required for dynamic equilibrium.

10.6 For the mechanism shown in Figure P10.4, member 2 has a mass of 1 kg and a moment of inertia of 4000 kg mm$^2$ about its center of mass, $G_2$. Sliding block 1 has a constant velocity of 2.4 m/s upward.

(a) Determine the instantaneous force $F_1$ required to produce the motion, assuming that sliding block 3 is massless.
(b) Determine the required instantaneous force $F_1$ if sliding block 3 has a mass of 0.5 kg.

10.7 The slider-crank mechanism of Figure P10.5 has a constant crank angular velocity of 50 rad/s counterclockwise. The acceleration polygon is shown in the figure. The connecting rod has a mass of 1 kg, with a mass moment of inertia about its center of mass $G_2$, of 900 kg mm$^2$. The piston has a mass of 0.75 kg. Determine all bearing forces and the required input torque $T_1$ for the position shown.
10.8 The crank of the slider-crank mechanism of Figure P10.6 has an instantaneous angular velocity of 10 rad/s clockwise and an angular acceleration of 200 rad/s² clockwise. Information related to acceleration is given in the figure. The connecting rod has a mass of 15 kg and a mass moment of inertia of 7500 kg · mm² about its center of mass, G₂. The slider has a mass of 8 kg. The crank has a moment of inertia of 4000 kg · mm² about its stationary center of mass, G₁. Determine all bearing forces and the input torque \( T₁ \) for the position shown.

10.9 The four-bar linkage of Figure P10.7 has a constant input angular velocity \( \omega₁ = 200 \text{ rad/s} \) clockwise. This results in the following accelerations: \( a_{G₂} = 690 / 298 \text{ m/s}² \), \( \alpha₂ = 2670 \text{ rad/s}² \text{ ccw} \), \( a_{G₃} = 292 / 294 \text{ m/s}² \), and \( \alpha₃ = 6940 \text{ rad/s}² \text{ cw} \). Coupler link 2 has a mass of 0.78 kg and has a mass moment of inertia about center of mass, G₂, equal to 3000 kg mm². Follower link 3 has a mass of 0.65 kg and has a mass moment of inertia about its
center of mass, $G_3$, equal to 200 kg mm$^2$. Determine all bearing forces and instantaneous input torque $T_1$ by (a) a graphical solution and (b) an analytical solution.

10.10 The four-bar linkage of Figure P10.8 has a constant input angular velocity $\omega_1 = 60$ rad/s counterclockwise. The acceleration polygon is shown in the figure. The masses of coupler link 2 and follower link 3 are 1.0 kg and 0.6 kg, respectively, and the moments of inertia about the centers of mass are 700 kg mm$^2$ and 500 kg mm$^2$, respectively. Determine all bearing forces and instantaneous torque $T_1$ by (a) a graphical solution and (b) an analytical solution.
10.11 For the mechanism of Problem 10.10, determine the bearing forces and input torque if the constant-input angular velocity of 60 rad/s is clockwise rather than counterclockwise. How do the forces change if the input speed is doubled?

10.12 The four-bar linkage of Figure P10.9 has the following masses and moments of inertia: 
\[ m_1 = 1.9 \text{ kg}, \quad m_2 = 3.2 \text{ kg}, \quad m_3 = 2.6 \text{ kg}, \quad I_{G1} = 0.01 \text{ kg m}^2, \quad I_{G2} = 0.03 \text{ kg m}^2, \quad \text{and} \quad I_{G3} = 0.03 \text{ kg m}^2. \]
Input link 1 has instantaneous angular velocity and acceleration of 10 rad/s clockwise and 100 rad/s² counterclockwise, respectively, leading to the following accelerations: 
\[ a_{G1} = 12,720 \angle 195^\circ \text{ mm/s}^2, \quad a_{G2} = 24,800 \angle 189^\circ \text{ mm/s}^2, \quad a_{G3} = 12,200 \angle 182^\circ \text{ mm/s}^2. \]

\[ O_1B = 180 \text{ mm}, \quad O_1G_1 = 90 \text{ mm}, \quad BC = 300 \text{ mm}, \quad BG_2 = 150 \text{ mm}, \quad O_2C = 240 \text{ mm}, \quad O_3G_3 = 120 \text{ mm}. \]

\[ \alpha_2 = 19 \text{ rad/s}^2 \text{ ccw}, \quad \text{and} \quad \alpha_3 = 77 \text{ rad/s}^2 \text{ ccw}. \]

Determine the bearing forces and instantaneous input torque \( T_1 \) by (a) a graphical solution and (b) an analytical solution.

10.13 An in-line slider-crank mechanism has a crank length of 0.1 m and a connecting-rod length of 0.5 m. The piston has a mass of 3 kg. The connecting rod has a mass of 2 kg with a center of mass located at a distance of 0.15 m from the crankpin end of the rod. Utilizing a lumped-mass approximation for the connecting rod, determine an expression for the torque required to maintain a constant crank speed of 200 rev/min. Evaluate the torque on the following crank angles \( \phi: 0^\circ, 30^\circ, 60^\circ, 90^\circ, 120^\circ, 150^\circ, \text{ and } 180^\circ. \)

10.14 For the mechanism of Problem 10.13, determine the magnitudes and directions of all bearing forces for crank angle \( \phi = 0^\circ, 45^\circ, 90^\circ, 135^\circ, \text{ and } 180^\circ. \) Assume that the center of mass of the crank is stationary.

10.15 An in-line slider-crank mechanism has a crank length of 0.48 m and a connecting-rod length of 1.68 m. The piston has a mass of 65 kg. The connecting rod has a mass of 49 kg with a center of gravity located at a distance of 0.48 m from the crankpin end of the rod. Utilizing a lumped-mass approximation for the connecting rod, determine an expression for the torque required to maintain a constant crank speed of 60 rev/min. Evaluate the torque for the following crank angles \( \phi: 0^\circ, 30^\circ, 60^\circ, 90^\circ, 120^\circ, 150^\circ, \text{ and } 180^\circ. \)

10.16 For the mechanism of Problem 10.15, determine the magnitudes and directions of all bearing forces for crank angle \( \phi = 0^\circ, 45^\circ, 90^\circ, 135^\circ, \text{ and } 180^\circ. \) The crank is balanced.

10.17 Derive an expression for input torque \( T_1 \) similar to Eq. (10.37) for the offset slider-crank mechanism of Figure P10.10 with constant crank angular velocity \( \omega_1. \) For the parameter values of Problem 10.13 and an offset \( e \) of 0.1 m, evaluate the torque at the following crank angles \( \phi: 0^\circ, 30^\circ, 60^\circ, 90^\circ, 120^\circ, 150^\circ, \text{ and } 180^\circ. \)
10.18 Determine the torque $T_1$ required to maintain a constant crank speed of 1,000 rev/min ccw for the two-cylinder engine depicted in Figure P10.11. The individual pistons and connecting rods have masses of 1.0 kg and 0.8 kg, respectively. Consider the case where the cylinder V angle $\psi$ is 90°, the crank spacing $\theta$ is 90°, and the crank angle $\phi$ is $160^\circ \cdot BG_2 = DG_3 = 105$ mm.

\[
\begin{align*}
O_1B &= O_1D = 50 \text{ mm} \\
BC &= DE = 210 \text{ mm} \\
BG_2 &= DG_3 = 105 \text{ mm}
\end{align*}
\]

10.19 Determine the torque $T_1$ required to maintain a constant crank speed of 1,000 rev/min ccw for the two-cylinder engine depicted in Figure P10.12. The individual pistons and connecting rods have masses of 1.0 kg and 0.8 kg, respectively. Consider the case where the cylinder V-angle $\psi$ is 90° and the crank angle $\phi$ is 20°. $BG_2 = BG_3 = 100$ mm.

10.20 Figure P10.13 is a schematic of a three-bladed propeller. Determine the location and correction amount of the counterweight that will balance the rotor. Perform the solution by using (a) the graphical method and (b) the analytical method.

10.21 Determine the corrections needed in planes $P$ and $Q$ to balance the rotor shown in Figure P10.14. Carry out the solution by (a) the graphical method and (b) the analytical method.