

PROBLEM 8-25

Statement: Write a computer program or use an equation solver such as Mathcad or TKSolver to calculate and plot the $s v a j$ diagrams for a 4-5-6-7 polynomial displacement cam function for any specified values of lift and duration. Test it using a lift of 20 mm over an interval of 60 deg at 1 rad/sec.

Enter: Lift: $h := 20\text{-mm}$

Duration: $\beta := 60\cdot\text{deg}$

Solution: See Mathcad file P0825.

1. The 4-5-6-7 polynomial is defined in local coordinates by equation 8.25. Differentiate it to get v, a , and j .

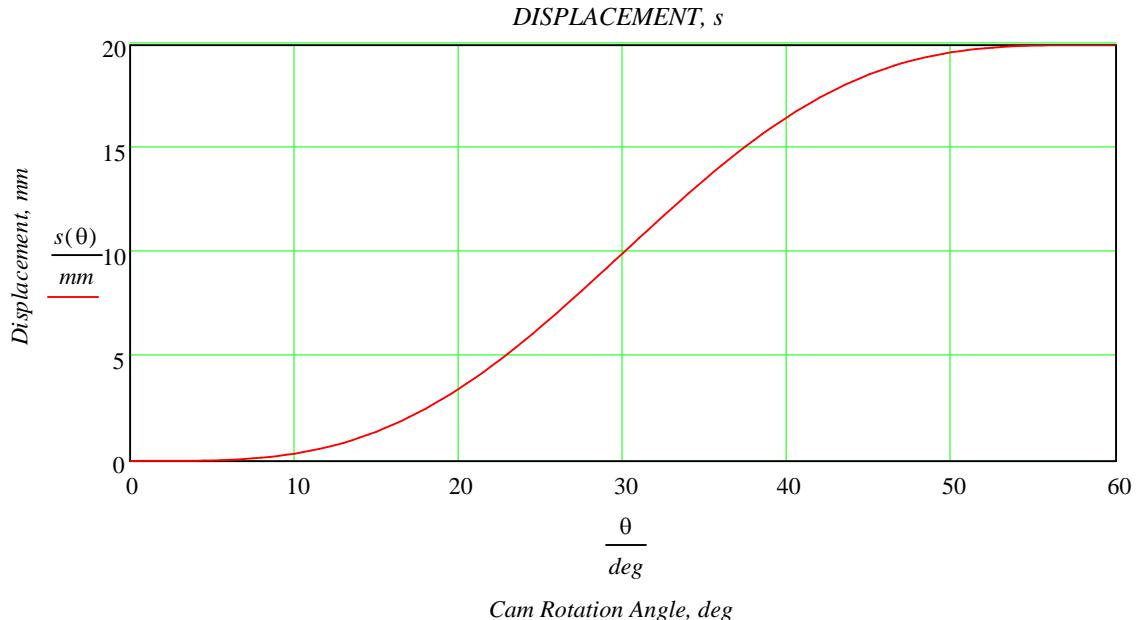
$$s(\theta) := h \left[35 \left(\frac{\theta}{\beta} \right)^4 - 84 \left(\frac{\theta}{\beta} \right)^5 + 70 \left(\frac{\theta}{\beta} \right)^6 - 20 \left(\frac{\theta}{\beta} \right)^7 \right]$$

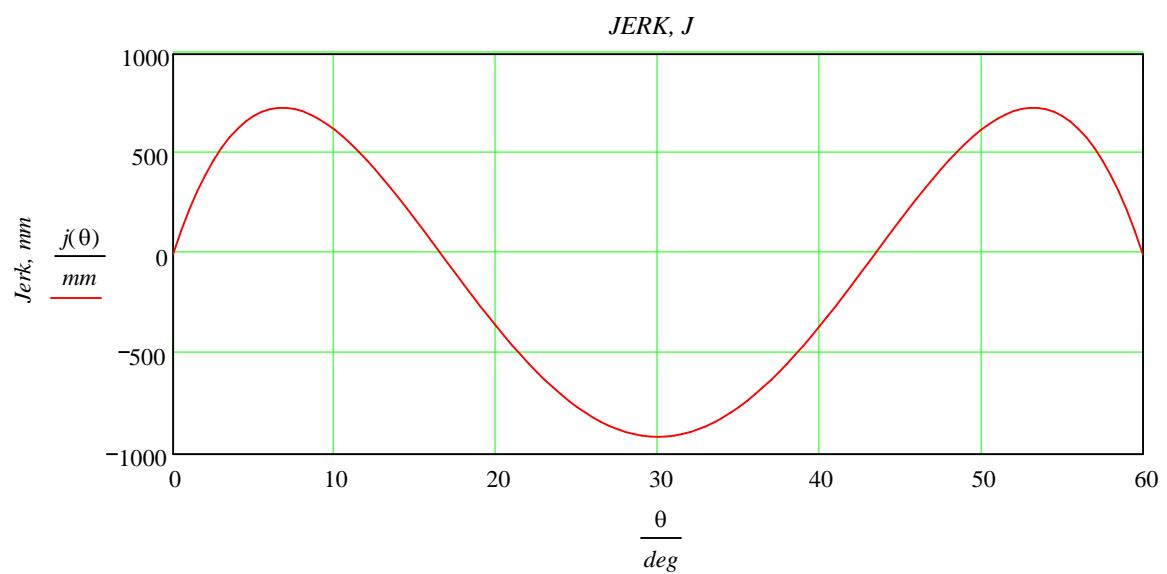
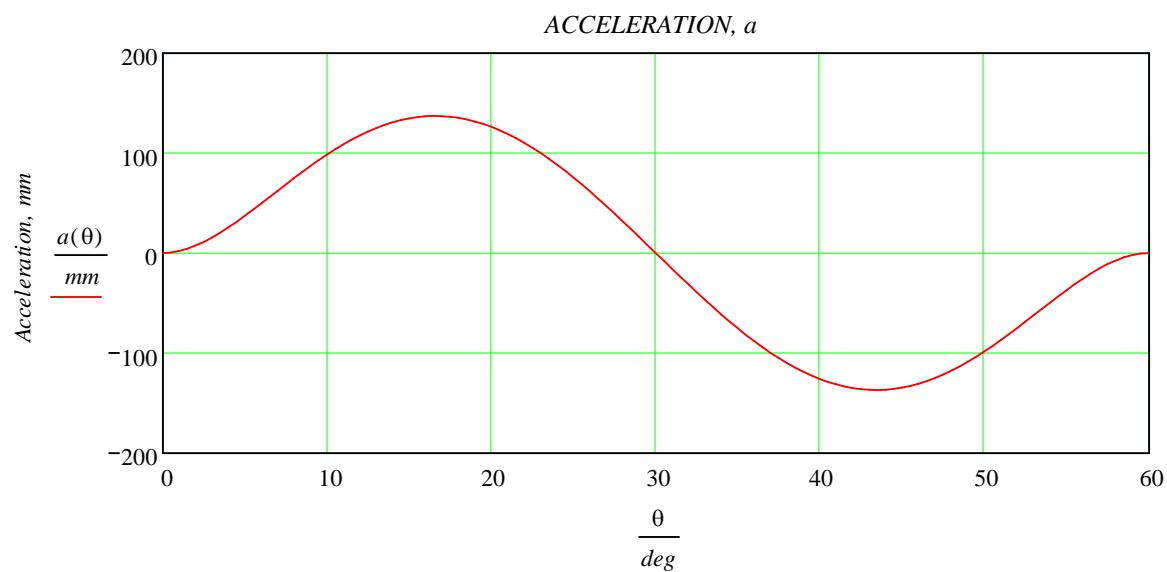
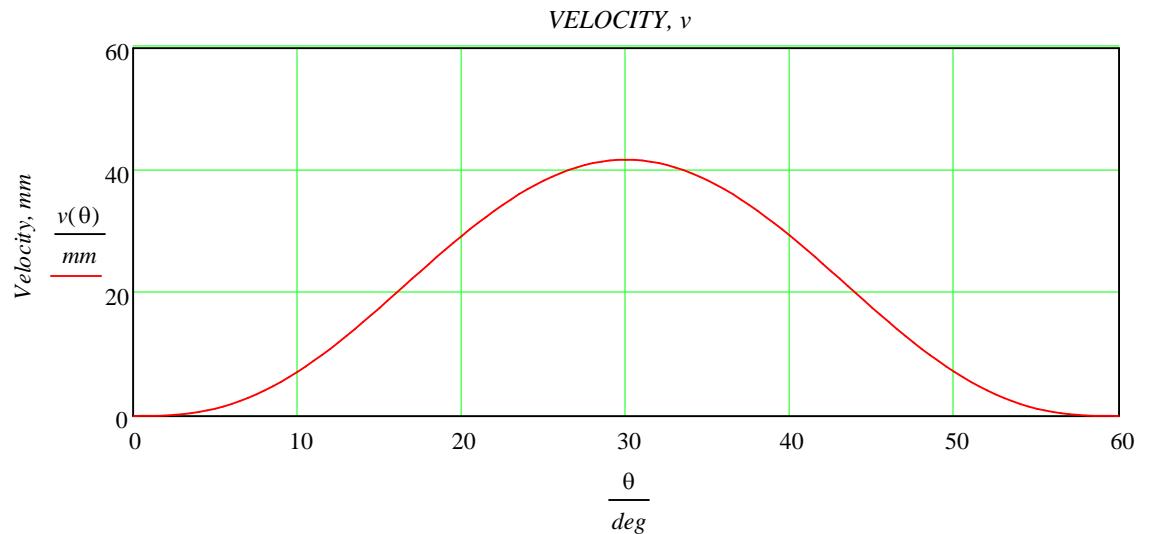
$$v(\theta) := \frac{h}{\beta} \left[140 \left(\frac{\theta}{\beta} \right)^3 - 420 \left(\frac{\theta}{\beta} \right)^4 + 420 \left(\frac{\theta}{\beta} \right)^5 - 140 \left(\frac{\theta}{\beta} \right)^6 \right]$$

$$a(\theta) := \frac{h}{\beta^2} \left[420 \left(\frac{\theta}{\beta} \right)^2 - 1680 \left(\frac{\theta}{\beta} \right)^3 + 2100 \left(\frac{\theta}{\beta} \right)^4 - 840 \left(\frac{\theta}{\beta} \right)^5 \right]$$

$$j(\theta) := \frac{h}{\beta^3} \left[840 \left(\frac{\theta}{\beta} \right) - 5040 \left(\frac{\theta}{\beta} \right)^2 + 8400 \left(\frac{\theta}{\beta} \right)^3 - 4200 \left(\frac{\theta}{\beta} \right)^4 \right]$$

2. Plot the displacement, velocity, acceleration, and jerk functions over the lift interval: $\theta := 0\cdot\text{deg}, 0.5\cdot\text{deg..}\beta$





PROBLEM 8-22

Statement: Write a computer program or use an equation solver such as Mathcad or TKSolver to calculate and plot the $s v a j$ diagrams for a modified sinusoidal acceleration cam function for any specified values of lift and duration. Test it using a lift of 20 mm over an interval of 60 deg at 1 rad/sec.

Enter:

Lift:	$h_I := 20 \cdot \text{mm}$
Duration:	$\beta_I := 60 \cdot \text{deg}$

Solution: See Mathcad file P0822.

1. Enter values for lift and duration above.
2. The numerical constants in these SCCA for the modified trapezoidal equations are given in Table 8-2.

$$\begin{aligned} b &\approx 0.25 & c &\approx 0.00 & d &\approx 0.75 \\ C_v &:= 1.7596 & C_a &:= 5.5280 & C_j &:= 69.466 \end{aligned}$$

3. The SCCA equations for the rise or fall interval (β) are divided into 5 subintervals. These are:

for $0 \leq x \leq b/2$ where, for these equations, x is a local coordinate that ranges from 0 to 1,

$$\begin{aligned} y_I(x) &:= C_a \left[x \cdot \frac{b}{\pi} - \left(\frac{b}{\pi} \right)^2 \cdot \sin \left(\frac{\pi}{b} \cdot x \right) \right] & y'_I(x) &:= C_a \cdot \frac{b}{\pi} \cdot \left(1 - \cos \left(\frac{\pi}{b} \cdot x \right) \right) \\ y''_I(x) &:= C_a \cdot \sin \left(\frac{\pi}{b} \cdot x \right) & y'''_I(x) &:= C_a \cdot \frac{\pi}{b} \cdot \cos \left(\frac{\pi}{b} \cdot x \right) \end{aligned}$$

for $b/2 \leq x \leq (1 - d)/2$

$$\begin{aligned} y_2(x) &:= C_a \left[\frac{x^2}{2} + b \cdot \left(\frac{1}{\pi} - \frac{1}{2} \right) \cdot x + b^2 \cdot \left(\frac{1}{8} - \frac{1}{\pi^2} \right) \right] & y'_2(x) &:= C_a \left[x + b \cdot \left(\frac{1}{\pi} - \frac{1}{2} \right) \right] \\ y''_2(x) &:= C_a & y'''_2(x) &:= 0 \end{aligned}$$

for $(1 - d)/2 \leq x \leq (1 + d)/2$

$$\begin{aligned} y_3(x) &:= C_a \left[\left(\frac{b}{\pi} + \frac{c}{2} \right) \cdot x + \left(\frac{d}{\pi} \right)^2 + b^2 \cdot \left(\frac{1}{8} - \frac{1}{\pi^2} \right) - \frac{(1-d)^2}{8} - \left(\frac{d}{\pi} \right)^2 \cdot \cos \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right] \right] \\ y'_3(x) &:= C_a \left[\frac{b}{\pi} + \frac{c}{2} + \frac{d}{\pi} \cdot \sin \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right] \right] \\ y''_3(x) &:= C_a \cdot \cos \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right] & y'''_3(x) &:= -C_a \cdot \frac{\pi}{d} \cdot \sin \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right] \end{aligned}$$

for $(1 + d)/2 \leq x \leq 1 - b/2$

$$\begin{aligned} y_4(x) &:= C_a \left[-\frac{x^2}{2} + \left(\frac{b}{\pi} + 1 - \frac{b}{2} \right) \cdot x + (2 \cdot d^2 - b^2) \cdot \left(\frac{1}{\pi^2} - \frac{1}{8} \right) - \frac{1}{4} \right] \\ y'_4(x) &:= C_a \left[-x + \frac{b}{\pi} + 1 - \frac{b}{2} \right] & y''_4(x) &:= -C_a & y'''_4(x) &:= 0 \end{aligned}$$

for $1 - b/2 \leq x \leq 1$

$$y_5(x) := C_a \left[\frac{b}{\pi} \cdot x + \frac{2 \cdot (d^2 - b^2)}{\pi^2} + \frac{(1-b)^2 - d^2}{4} - \left(\frac{b}{\pi} \right)^2 \cdot \sin \left[\frac{\pi}{b} \cdot (x - 1) \right] \right]$$

$$y'_5(x) := C_a \cdot \frac{b}{\pi} \left[1 - \cos \left[\frac{\pi}{b} \cdot (x - 1) \right] \right]$$

$$y''_5(x) := C_a \sin \left[\frac{\pi}{b} \cdot (x - 1) \right]$$

$$y'''_5(x) := C_a \cdot \frac{\pi}{b} \cdot \cos \left[\frac{\pi}{b} \cdot (x - 1) \right]$$

4. The above equations can be used for a rise or fall by using the proper values of θ , β , and h . To plot the *SVAJ* curves, first define a range function that has a value of one between the values of $x1$ and $x2$ and zero elsewhere.

$$R(x, x1, x2) := \text{if}[(x > x1) \wedge (x \leq x2), 1, 0]$$

5. The global *SVAJ* equations are composed of four intervals (rise, dwell, fall, and dwell). The local equations above must be assembled into a single equation each for S , V , A , and J that applies over the range $0 \leq \theta \leq 360$ deg.
6. Write the local *svaj* equations for the first interval, $0 \leq \theta \leq \beta_1$. Note that each subinterval function is multiplied by the range function so that it will have nonzero values only over its subinterval.

For $0 \leq \theta \leq \beta_1$ (Rise)

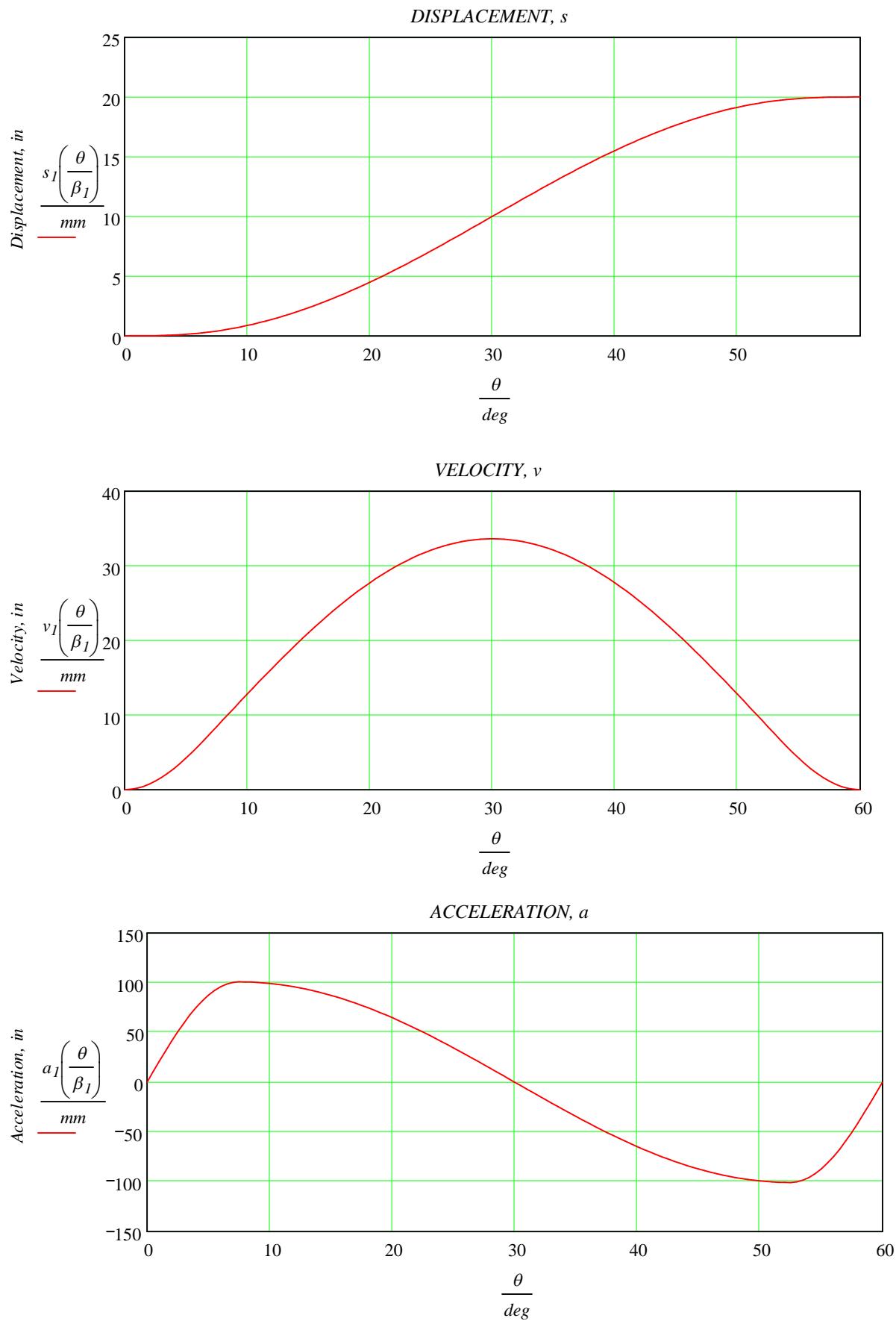
$$s_I(x) = h_I \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y_5(x) \right)$$

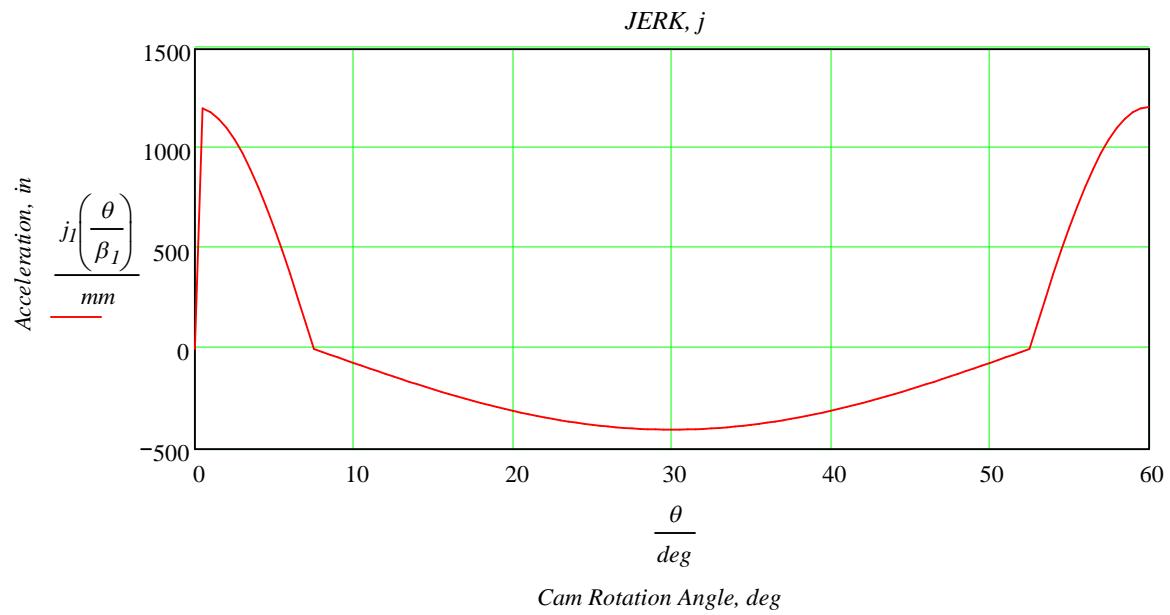
$$v_I(x) := \frac{h_I}{\beta_I} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y'_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y'_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y'_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y'_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y'_5(x) \right)$$

$$a_I(x) := \frac{h_I}{\beta_I^2} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y''_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y''_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y''_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y''_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y''_5(x) \right)$$

$$j_I(x) := \frac{h_I}{\beta_I^3} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y'''_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y'''_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y'''_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y'''_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y'''_5(x) \right)$$

5. Plot the displacement, velocity, acceleration, and jerk functions over the lift interval: $\theta := 0 \text{ deg}, 0.5 \text{ deg..} \beta_1$





PROBLEM 8-7

Statement: Design a double-dwell cam to move a follower from 0 to 2.5 in in 60 deg, dwell for 120 deg, fall 2.5 in in 30 deg and dwell for the remainder. The total cycle must take 4 sec. Choose suitable programs for rise and fall to minimize accelerations. Plot the s v a j diagrams.

Given:

RISE

DWELL

FALL

DWELL

$$\beta_1 := 60 \cdot \text{deg}$$

$$\beta_2 := 120 \cdot \text{deg}$$

$$\beta_3 := 30 \cdot \text{deg}$$

$$\beta_4 := 150 \cdot \text{deg}$$

$$h_1 := 2.5 \cdot \text{in}$$

$$h_2 := 0 \cdot \text{in}$$

$$h_3 := 2.5 \cdot \text{in}$$

$$h_4 := 0 \cdot \text{in}$$

$$\text{Cycle time: } \tau := 4 \cdot \text{sec}$$

Solution: See Mathcad file P0807.

1. The camshaft turns 2π rad during the time for one cycle. Thus, its speed is

$$\omega := \frac{2 \cdot \pi \cdot \text{rad}}{\tau} \quad \omega = 1.571 \frac{\text{rad}}{\text{sec}}$$

2. From Table 8-3, the motion program with lowest acceleration that does not have infinite jerk is the modified trapezoidal. The modified trapezoidal motion is defined in local coordinates by equations 8.15 through 8.19. The numerical constants in these SCCA equations are given in Table 8-2.

$$b := 0.25 \quad c := 0.50 \quad d := 0.25$$

$$C_v := 2.0000 \quad C_a := 4.8881 \quad C_j := 61.426$$

3. The SCCA equations for the rise or fall interval (β) are divided into 5 subintervals. These are:

for $0 \leq x \leq b/2$ where, for these equations, x is a local coordinate that ranges from 0 to 1,

$$y_1(x) := C_a \left[x \cdot \frac{b}{\pi} - \left(\frac{b}{\pi} \right)^2 \cdot \sin \left(\frac{\pi}{b} \cdot x \right) \right] \quad y'_1(x) := C_a \cdot \frac{b}{\pi} \left(1 - \cos \left(\frac{\pi}{b} \cdot x \right) \right)$$

$$y''_1(x) := C_a \cdot \sin \left(\frac{\pi}{b} \cdot x \right) \quad y'''_1(x) := C_a \cdot \frac{\pi}{b} \cdot \cos \left(\frac{\pi}{b} \cdot x \right)$$

for $b/2 \leq x \leq (1 - d)/2$

$$y_2(x) := C_a \left[\frac{x^2}{2} + b \cdot \left(\frac{1}{\pi} - \frac{1}{2} \right) \cdot x + b^2 \cdot \left(\frac{1}{8} - \frac{1}{\pi^2} \right) \right] \quad y'_2(x) := C_a \left[x + b \cdot \left(\frac{1}{\pi} - \frac{1}{2} \right) \right]$$

$$y''_2(x) := C_a \quad y'''_2(x) := 0$$

for $(1 - d)/2 \leq x \leq (1 + d)/2$

$$y_3(x) := C_a \left[\left(\frac{b}{\pi} + \frac{c}{2} \right) \cdot x + \left(\frac{d}{\pi} \right)^2 + b^2 \cdot \left(\frac{1}{8} - \frac{1}{\pi^2} \right) - \frac{(1-d)^2}{8} - \left(\frac{d}{\pi} \right)^2 \cdot \cos \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right] \right]$$

$$y'_3(x) := C_a \left[\frac{b}{\pi} + \frac{c}{2} + \frac{d}{\pi} \cdot \sin \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right] \right]$$

$$y''_3(x) := C_a \cdot \cos \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right] \quad y'''_3(x) := -C_a \cdot \frac{\pi}{d} \cdot \sin \left[\frac{\pi}{d} \cdot \left(x - \frac{1-d}{2} \right) \right]$$

for $(1 + d)/2 \leq x \leq 1 - b/2$

$$y_4(x) := C_a \cdot \left[-\frac{x^2}{2} + \left(\frac{b}{\pi} + 1 - \frac{b}{2} \right) \cdot x + \left(2 \cdot d^2 - b^2 \right) \cdot \left(\frac{1}{\pi^2} - \frac{1}{8} \right) - \frac{1}{4} \right]$$

$$y'_4(x) := C_a \cdot \left(-x + \frac{b}{\pi} + 1 - \frac{b}{2} \right) \quad y''_4(x) := -C_a \quad y'''_4(x) := 0$$

for $1 - b/2 \leq x \leq 1$

$$y_5(x) := C_a \cdot \left[\frac{b}{\pi} \cdot x + \frac{2 \cdot (d^2 - b^2)}{\pi^2} + \frac{(1-b)^2 - d^2}{4} - \left(\frac{b}{\pi} \right)^2 \cdot \sin \left[\frac{\pi}{b} \cdot (x-1) \right] \right]$$

$$y'_5(x) := C_a \cdot \frac{b}{\pi} \cdot \left[1 - \cos \left[\frac{\pi}{b} \cdot (x-1) \right] \right]$$

$$y''_5(x) := C_a \cdot \sin \left[\frac{\pi}{b} \cdot (x-1) \right] \quad y'''_5(x) := C_a \cdot \frac{\pi}{b} \cdot \cos \left[\frac{\pi}{b} \cdot (x-1) \right]$$

4. The above equations can be used for a rise or fall by using the proper values of θ , β , and h . To plot the SVAJ curves, first define a range function that has a value of one between the values of $x1$ and $x2$ and zero elsewhere.

$$R(x, x1, x2) := if[(x > x1) \wedge (x \leq x2), 1, 0]$$

5. The global SVAJ equations are composed of four intervals (rise, dwell, fall, and dwell). The local equations above must be assembled into a single equation each for S , V , A , and J that applies over the range $0 \leq \theta \leq 360$ deg.
6. Write the local svaj equations for the first interval, $0 \leq \theta \leq \beta_1$. Note that each subinterval function is multiplied by the range function so that it will have nonzero values only over its subinterval.

For $0 \leq \theta \leq \beta_1$ (Rise)

$$s_I(x) = h_I \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y_5(x) \right)$$

$$v_I(x) := \frac{h_I}{\beta_I} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y'_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y'_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y'_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y'_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y'_5(x) \right)$$

$$a_I(x) := \frac{h_I}{\beta_I^2} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y''_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y''_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y''_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y''_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y''_5(x) \right)$$

$$j_I(x) := \frac{h_I}{\beta_I^3} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y'''_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y'''_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y'''_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y'''_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y'''_5(x) \right)$$

7. Write the local *svaj* equations for the second interval, $\beta_1 \leq \theta \leq \beta_1 + \beta_2$. For this interval, the value of S is the value of S at the end of the previous interval and the values of V, A , and J are zero because of the dwell.

For $\beta_1 \leq \theta \leq \beta_1 + \beta_2$

$$s_2(x) := h_I \quad v_2(x) := 0 \quad a_2(x) := 0 \quad j_2(x) = 0$$

8. Write the local *svaj* equations for the third interval, $\beta_1 + \beta_2 \leq \theta \leq \beta_1 + \beta_2 + \beta_3$.

For $\beta_1 + \beta_2 \leq \theta \leq \beta_1 + \beta_2 + \beta_3$

$$s_3(x) := h_3 \left[1 - \left(R\left(x, 0, \frac{b}{2}\right) \cdot y_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y_3(x) \dots \right) \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y_5(x) \right]$$

$$v_3(x) := -\frac{h_3}{\beta_3} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y'_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y'_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y'_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y'_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y'_5(x) \right)$$

$$a_3(x) := -\frac{h_3}{\beta_3^2} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y''_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y''_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y''_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y''_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y''_5(x) \right)$$

$$j_3(x) := -\frac{h_3}{\beta_3^3} \cdot \left(R\left(x, 0, \frac{b}{2}\right) \cdot y'''_1(x) + R\left(x, \frac{b}{2}, \frac{1-d}{2}\right) \cdot y'''_2(x) + R\left(x, \frac{1-d}{2}, \frac{1+d}{2}\right) \cdot y'''_3(x) \dots \right. \\ \left. + R\left(x, \frac{1+d}{2}, 1 - \frac{b}{2}\right) \cdot y'''_4(x) + R\left(x, 1 - \frac{b}{2}, 1\right) \cdot y'''_5(x) \right)$$

9. Write the local *svaj* equations for the fourth interval, $\beta_1 + \beta_2 + \beta_3 \leq \theta \leq \beta_1 + \beta_2 + \beta_3 + \beta_4$. For this interval, the values of S, V, A , and J are zero because of the dwell.

For $\beta_1 + \beta_2 + \beta_3 \leq \theta \leq \beta_1 + \beta_2 + \beta_3 + \beta_4$

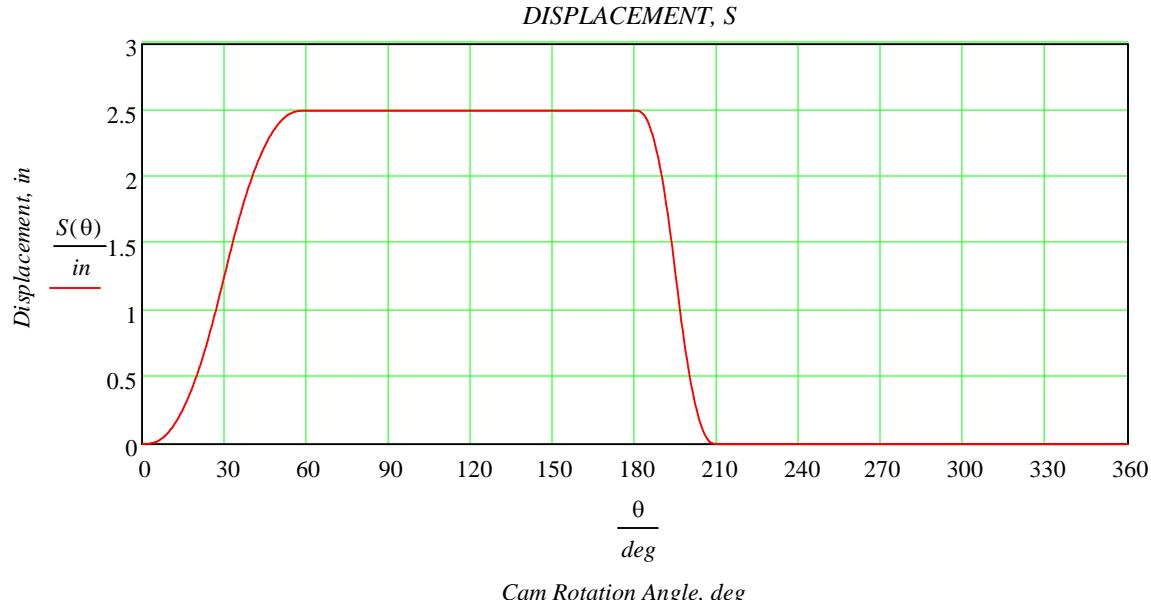
$$s_4(x) := 0 \quad v_4(x) := 0 \quad a_4(x) := 0 \quad j_4(x) := 0$$

10. Write the complete global equation for the displacement and plot it over one rotation of the cam, which is the sum of the four intervals defined above.

$$\text{Let } \theta_1 := \beta_1 \quad \theta_2 := \theta_1 + \beta_2 \quad \theta_3 := \theta_2 + \beta_3 \quad \theta_4 := \theta_3 + \beta_4$$

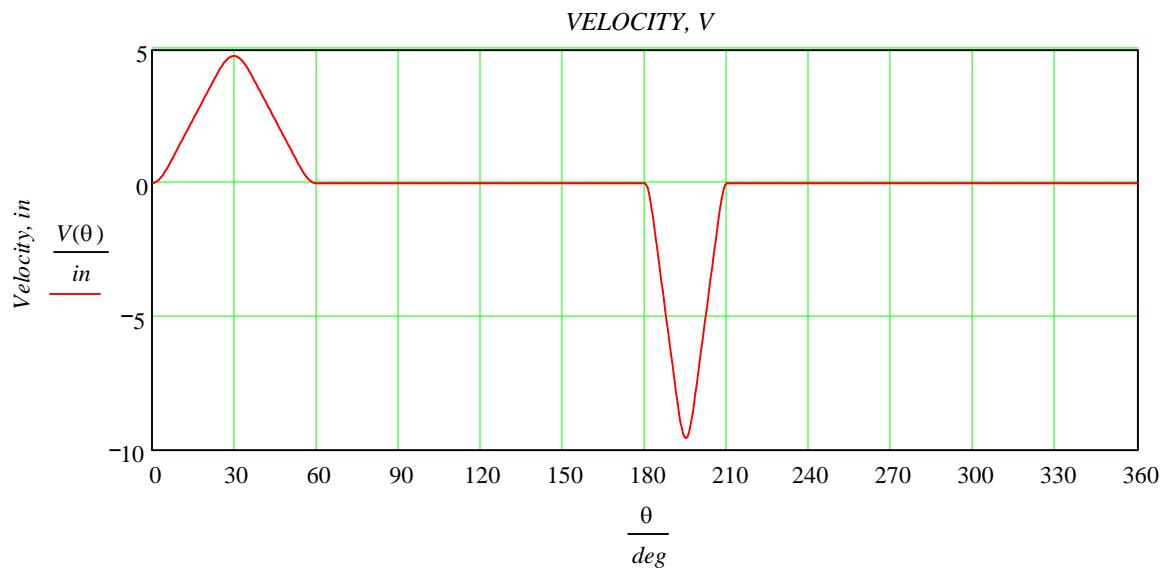
$$S(\theta) := s_1 \left(\frac{\theta}{\theta_1} \right) + R(\theta, \theta_1, \theta_2) \cdot s_2 \left(\frac{\theta - \theta_1}{\theta_2 - \theta_1} \right) \dots \\ + R(\theta, \theta_2, \theta_3) \cdot s_3 \left(\frac{\theta - \theta_2}{\theta_3 - \theta_2} \right) + R(\theta, \theta_3, \theta_4) \cdot s_4 \left(\frac{\theta - \theta_3}{\theta_4 - \theta_3} \right)$$

$$\theta := 0 \cdot \text{deg}, 0.5 \cdot \text{deg}..360 \cdot \text{deg}$$



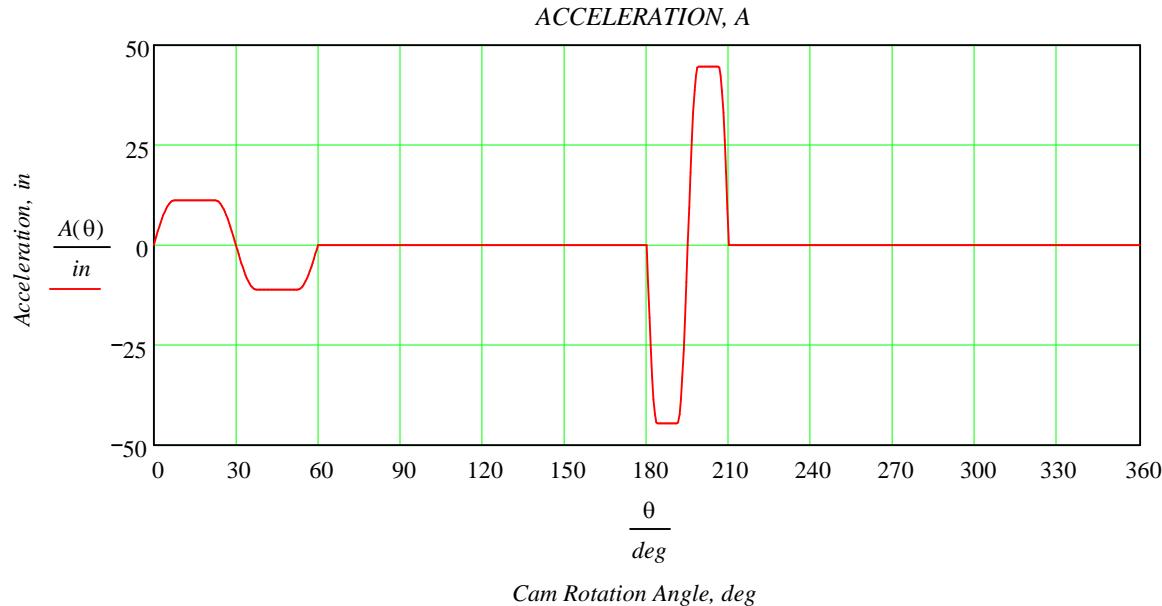
11. Write the complete global equation for the velocity and plot it over one rotation of the cam, which is the sum of the four intervals defined above.

$$V(\theta) = v_1 \left(\frac{\theta}{\theta_1} \right) + R(\theta, \theta_1, \theta_2) \cdot v_2 \left(\frac{\theta - \theta_1}{\theta_2 - \theta_1} \right) \dots \\ + R(\theta, \theta_2, \theta_3) \cdot v_3 \left(\frac{\theta - \theta_2}{\theta_3 - \theta_2} \right) + R(\theta, \theta_3, \theta_4) \cdot v_4 \left(\frac{\theta - \theta_3}{\theta_4 - \theta_3} \right)$$



12. Write the complete global equation for the acceleration and plot it over one rotation of the cam, which is the sum of the four intervals defined above.

$$A(\theta) = a_1 \left(\frac{\theta}{\theta_1} \right) + R(\theta, \theta_1, \theta_2) \cdot a_2 \left(\frac{\theta - \theta_1}{\theta_2 - \theta_1} \right) \dots \\ + R(\theta, \theta_2, \theta_3) \cdot a_3 \left(\frac{\theta - \theta_2}{\theta_3 - \theta_2} \right) + R(\theta, \theta_3, \theta_4) \cdot a_4 \left(\frac{\theta - \theta_3}{\theta_4 - \theta_3} \right)$$



13. Write the complete global equation for the jerk and plot it over one rotation of the cam, which is the sum of the four intervals defined above.

$$\begin{aligned} J(\theta) := & j_1 \left(\frac{\theta}{\theta_1} \right) + R(\theta, \theta_1, \theta_2) \cdot j_2 \left(\frac{\theta - \theta_1}{\theta_2 - \theta_1} \right) \dots \\ & + R(\theta, \theta_2, \theta_3) \cdot j_3 \left(\frac{\theta - \theta_2}{\theta_3 - \theta_2} \right) + R(\theta, \theta_3, \theta_4) \cdot j_4 \left(\frac{\theta - \theta_3}{\theta_4 - \theta_3} \right) \end{aligned}$$

