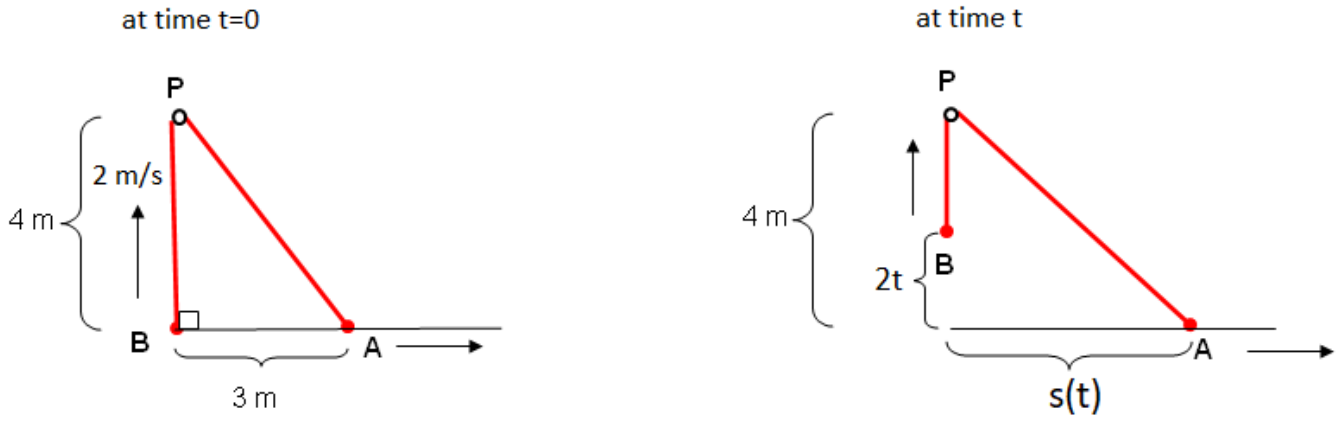
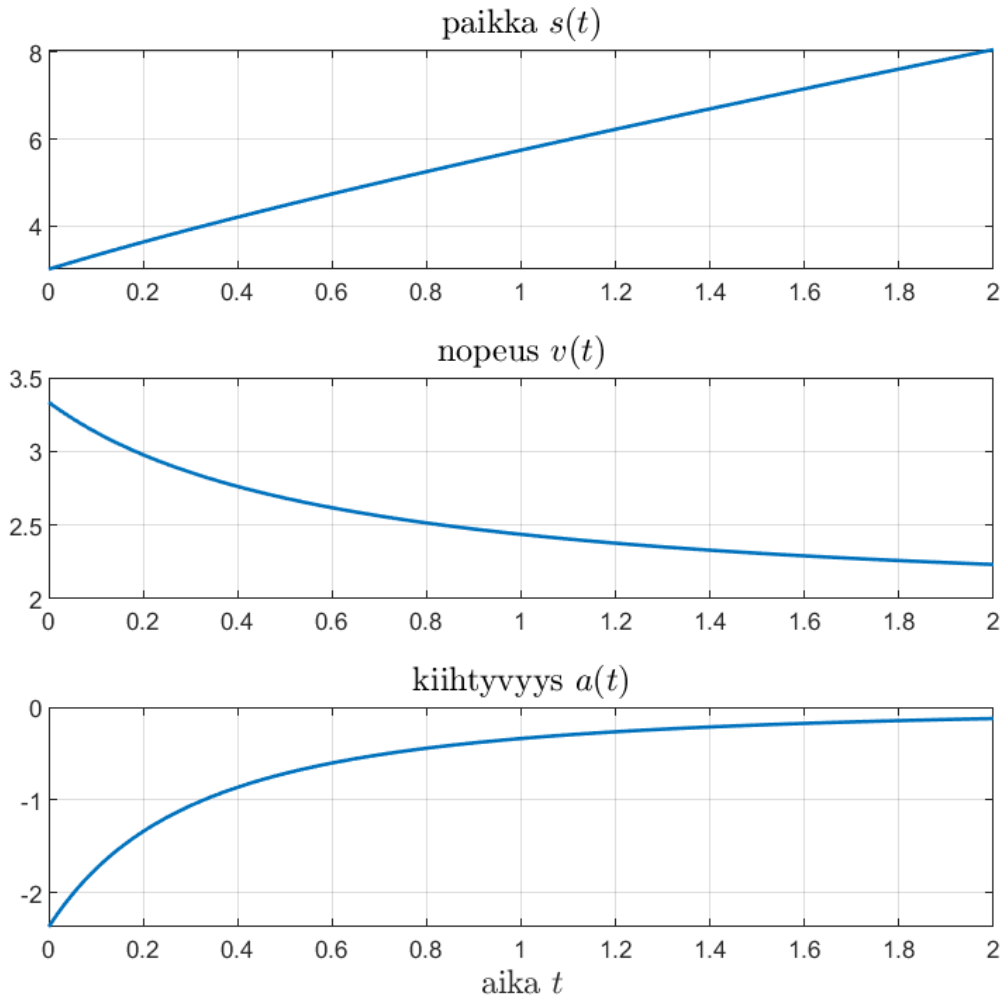
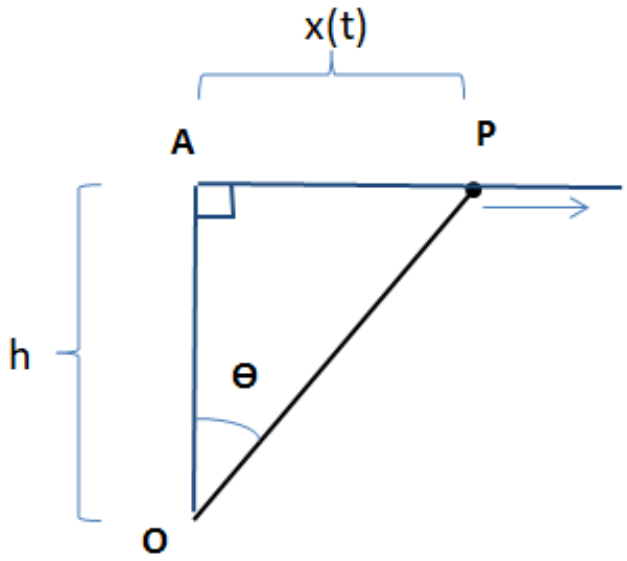
**1.** $B$ is moving up with velocity 2 m/s. Calculate the position, velocity and acceleration of $A$ and draw their graphs for $t = 0 \ldots 2$



**2.** Given height $h$, angle $\theta$, its angular velocity $\omega$ and acceleration $\alpha$, calculate the position $x(t)$ of $P$ and its velocity $x'(t)$ and acceleration $x''(t)$



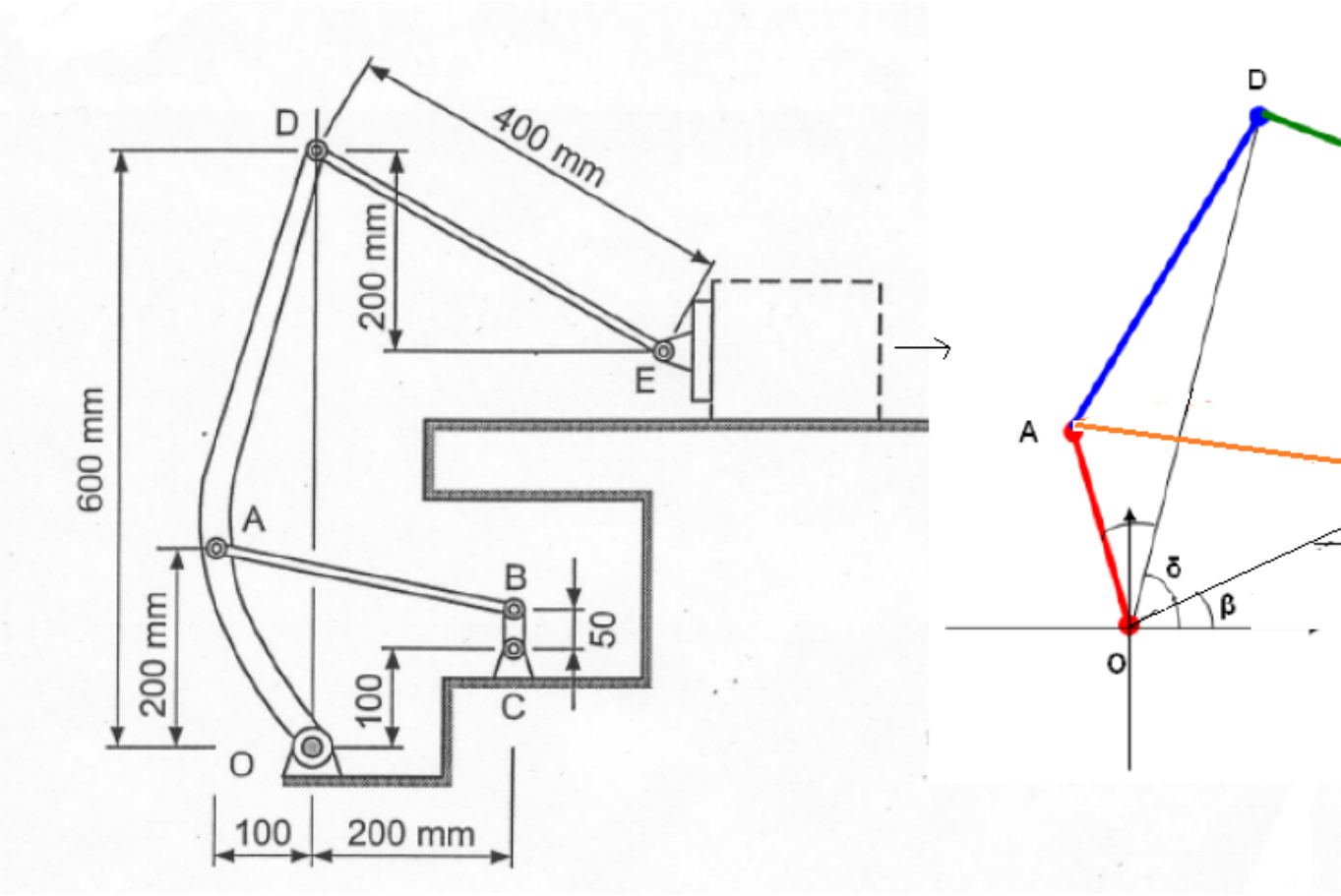

(ans: if

$h = 5,\ \theta = \pi/6,\ \omega = 2\pi,\ \alpha = -5\pi$

then

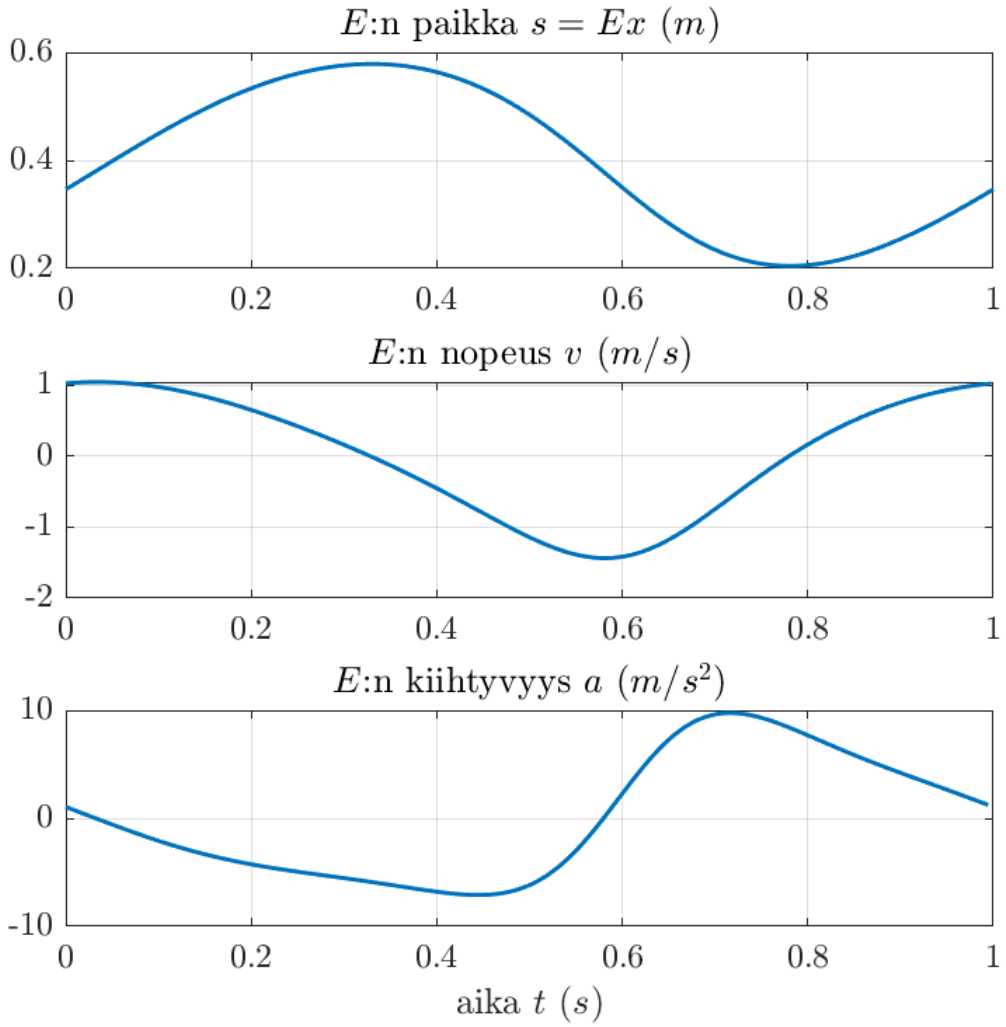
$x(t) = 2.89,\ x'(t) = 41.89,\ x''(t) = 199.19$)

**3.** Given the angular velocity $\omega$ (rad/sec) of $BC$, calculate values of the position, velocity and acceleration of point $E$ during one cycle

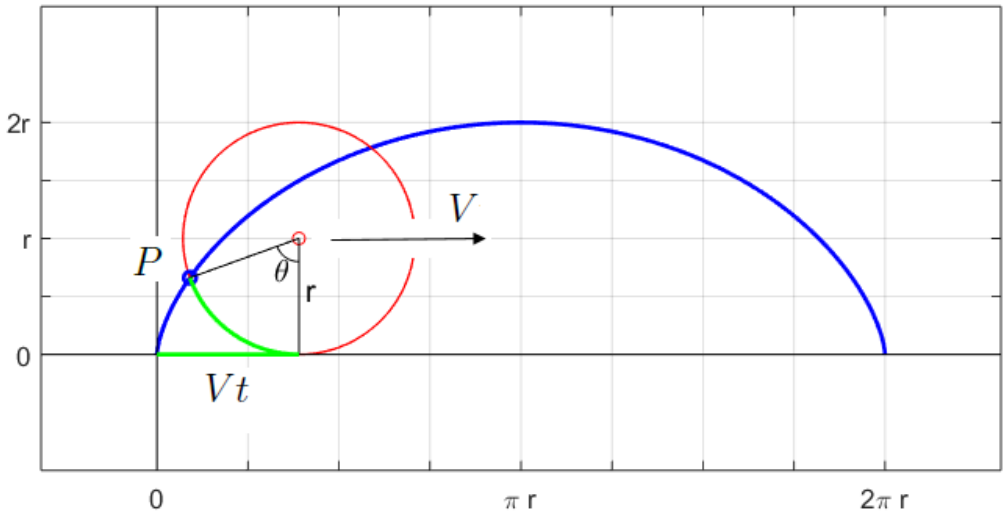


and draw a picture like below (when $\omega = 2\pi$),

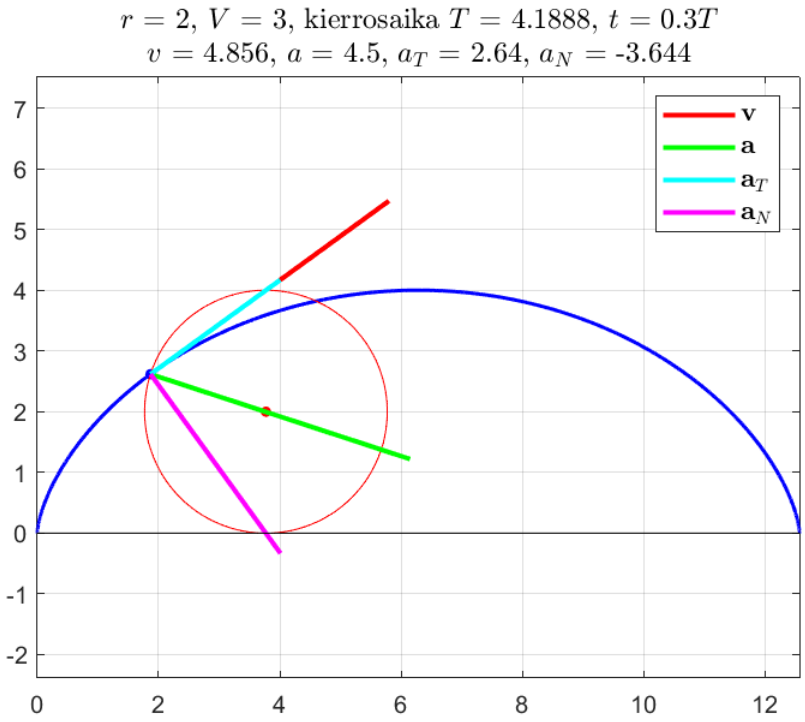
and create an animation showing the movement of the mechanism

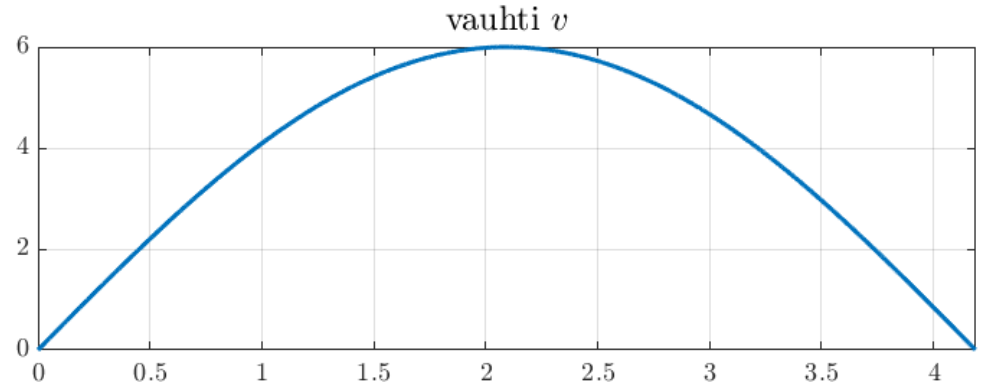


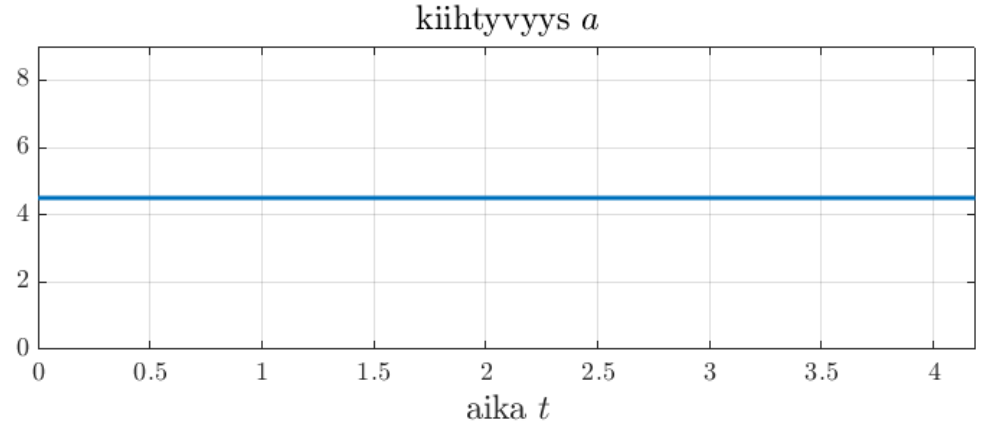
**4.** Cycloid is the trajectory of a point $P$ on the circle rolling on $x$-axis.

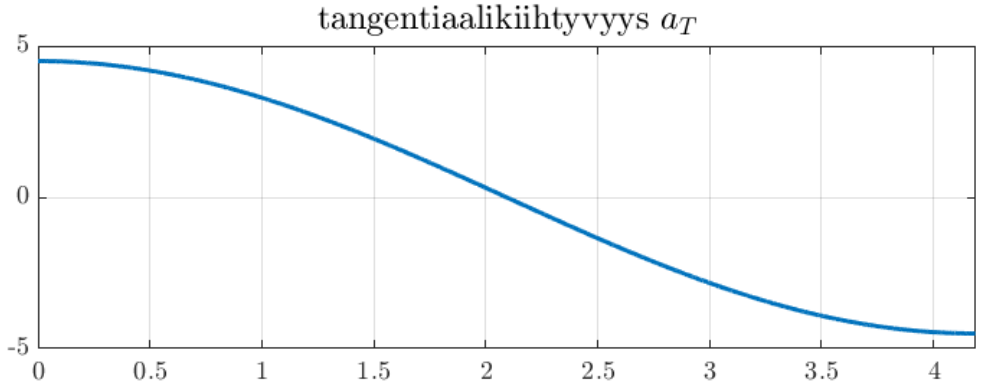


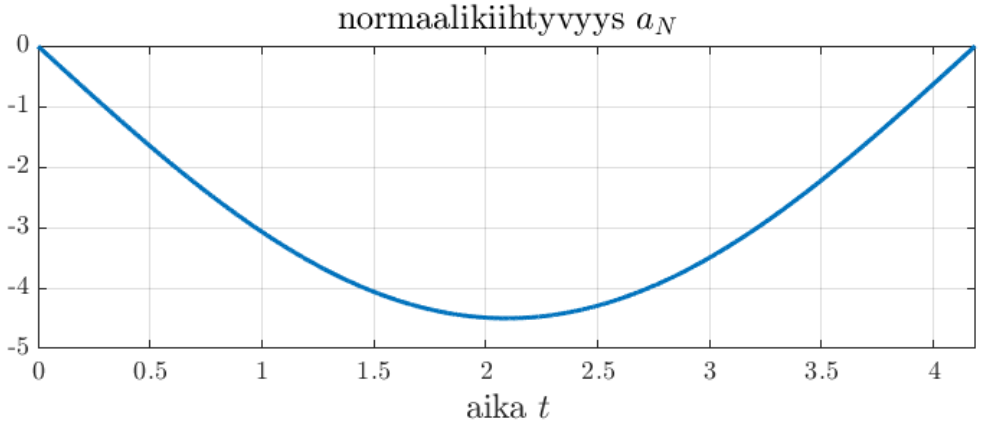

Given the radius $r$ and the velocity $V$ of the center, calculate the position, velocity and acceleration of $P$ and draw pictures like below (hint: $\theta$ = green arc/radius = $Vt/r$)



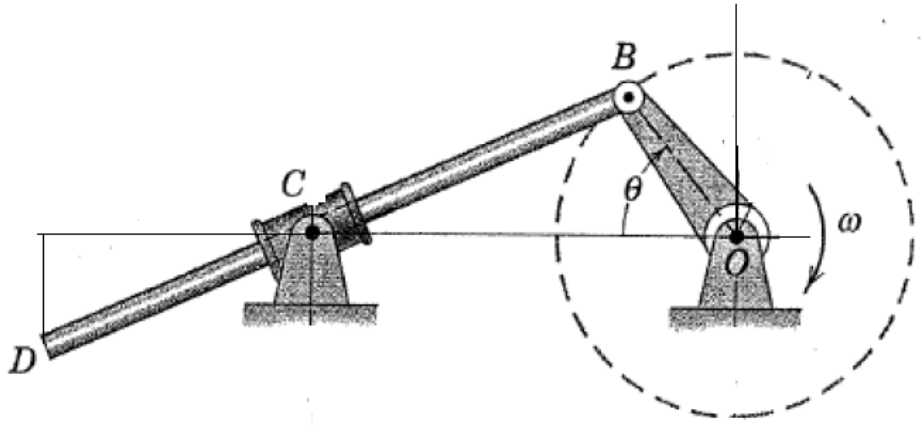

vauhti $v$
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4

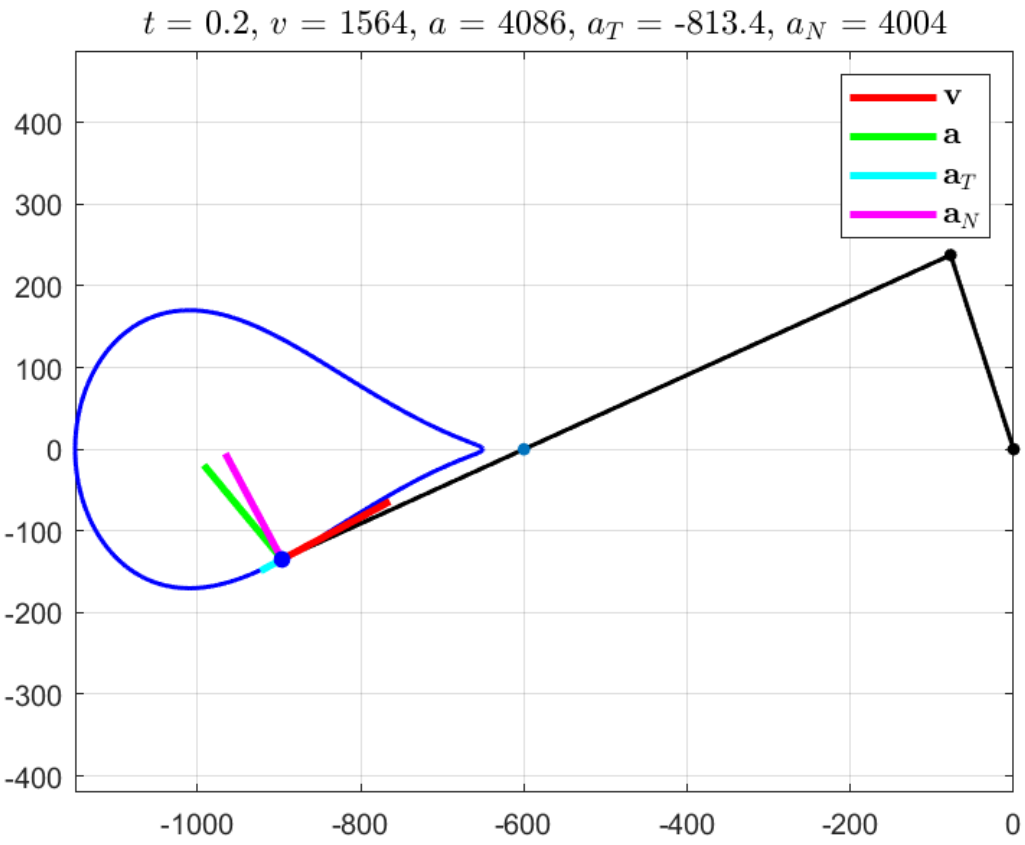

kiihtyvyys $a$
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
aika $t$

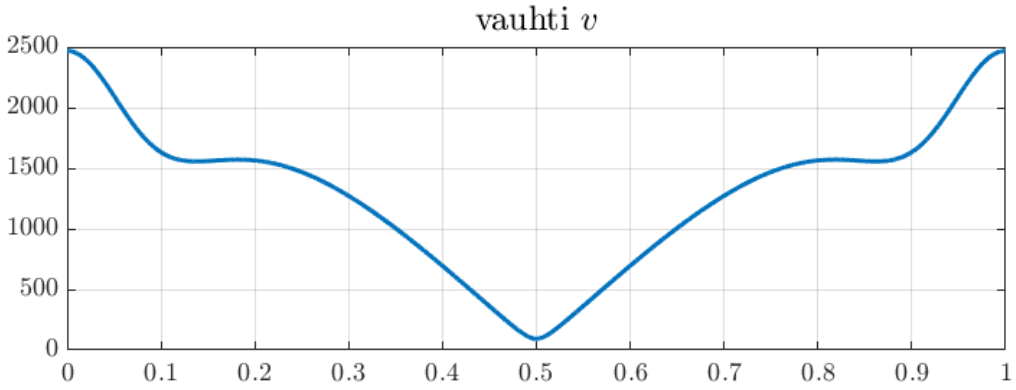

tangentiaalikiihtyvyys $a_T$
5
0
-5
0
0.5
1
1.5
2
2.5
3
3.5
4

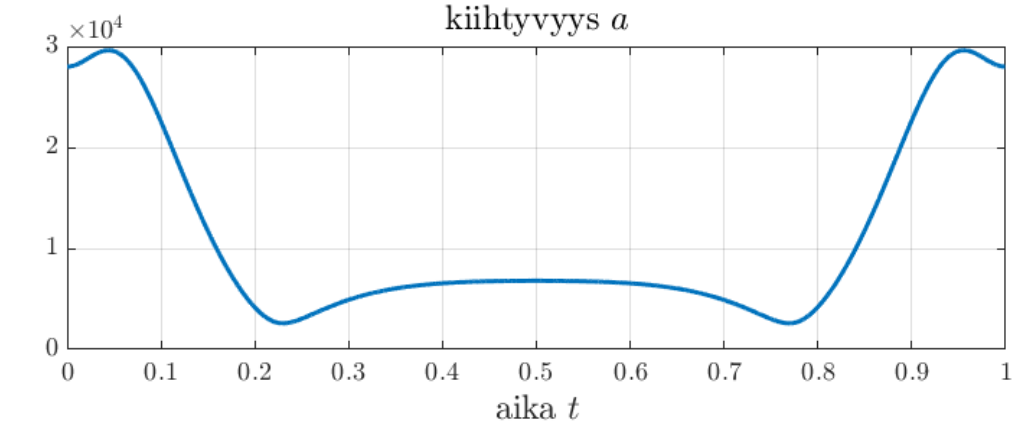

normaalikiihtyvyys $a_N$
0
-1
-2
-3
-4
-5
0
0.5
1
1.5
2
2.5
3
3.5
4
aika $t$

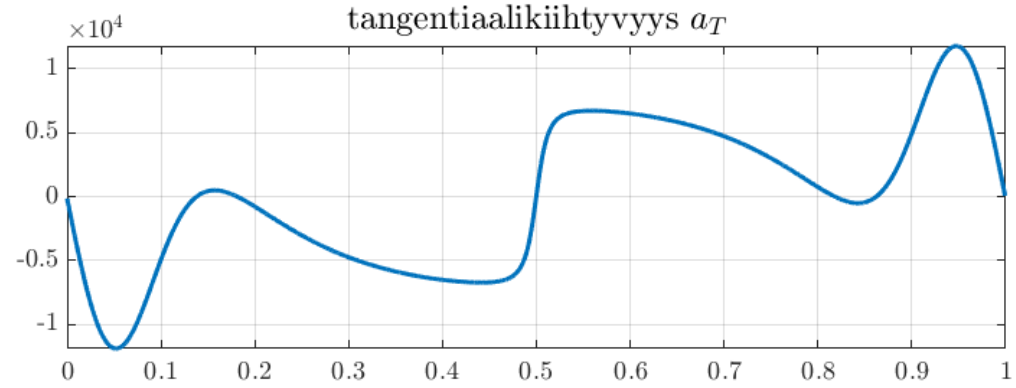
**5.** Given $OB = 250$, $OC = 600$, $BD = 900$ and angular velocity $\omega = 2\pi$ of $OB$ (i.e $\theta = \omega t$), calculate the position, velocity and acceleration of point $D$ and draw pictures like below

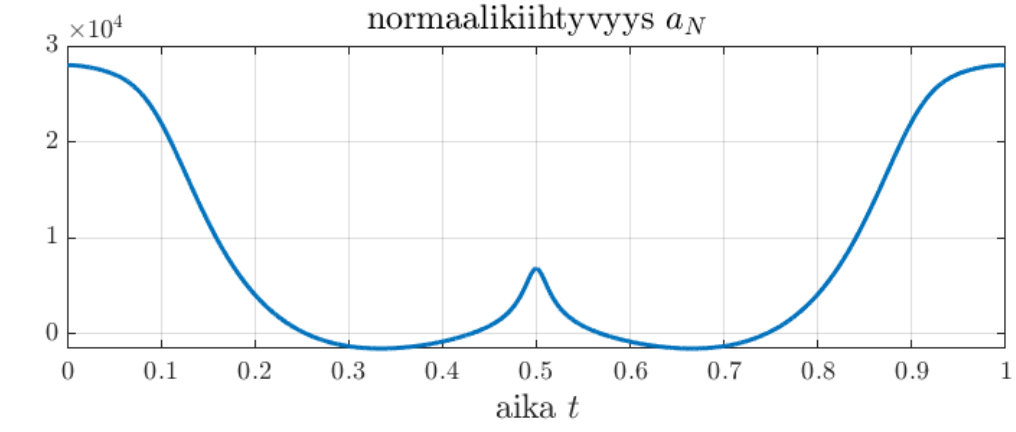


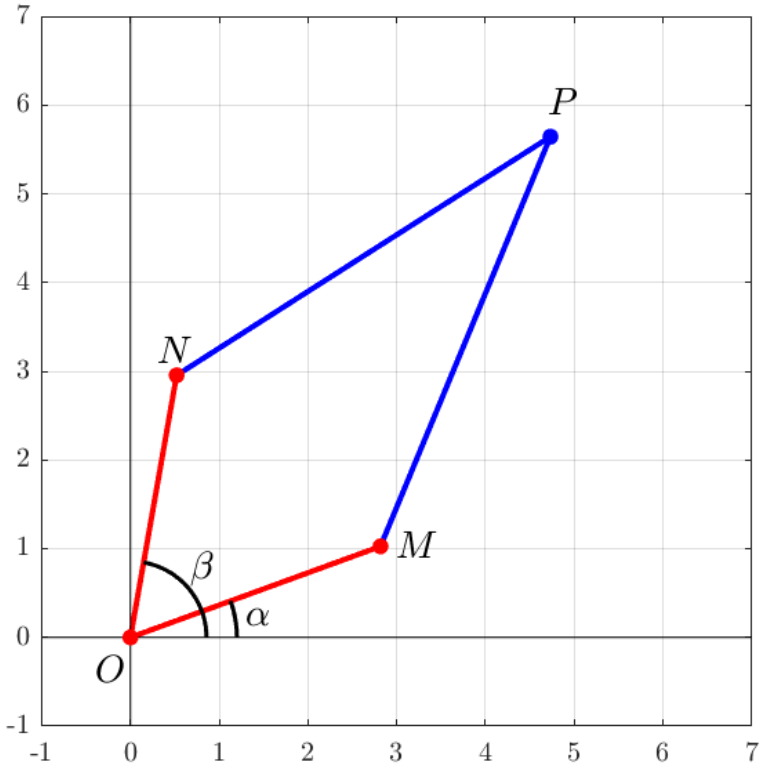

vauhti $v$
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

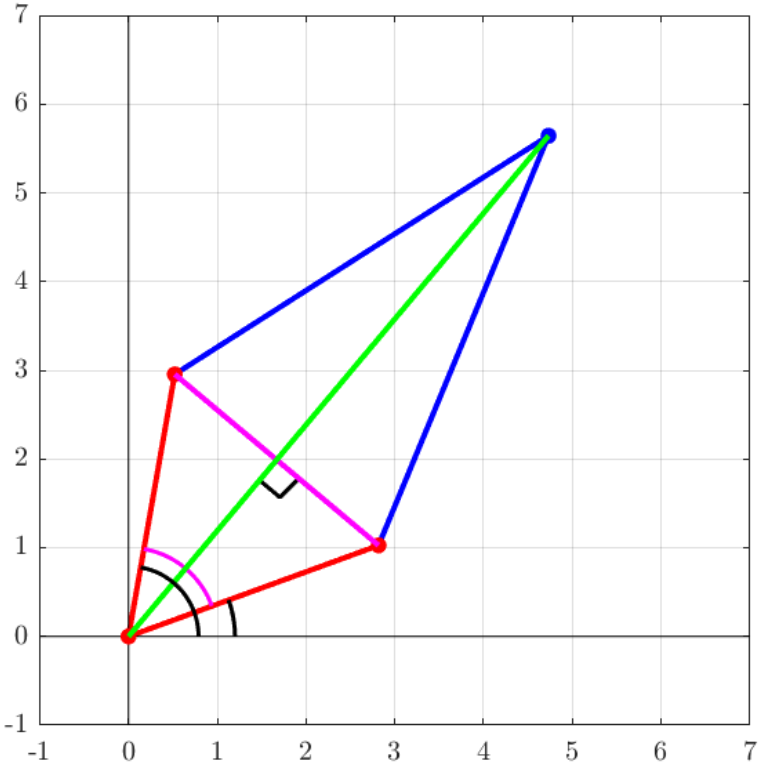

kiihtyvyys $a$
$\times 10^4$
3
2
1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
aika $t$


tangentiaalikiihtyvyys $a_T$
$\times 10^4$
1
0.5
0
-0.5
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


normaalikiihtyvyys $a_N$
$\times 10^4$
3
2
1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
aika $t$

**6.** (2D Delta-robot) Given lengths $R = OM = ON$ ja $L = MP = NP$, points $A$ and $B$ and duration time $T$, calculate



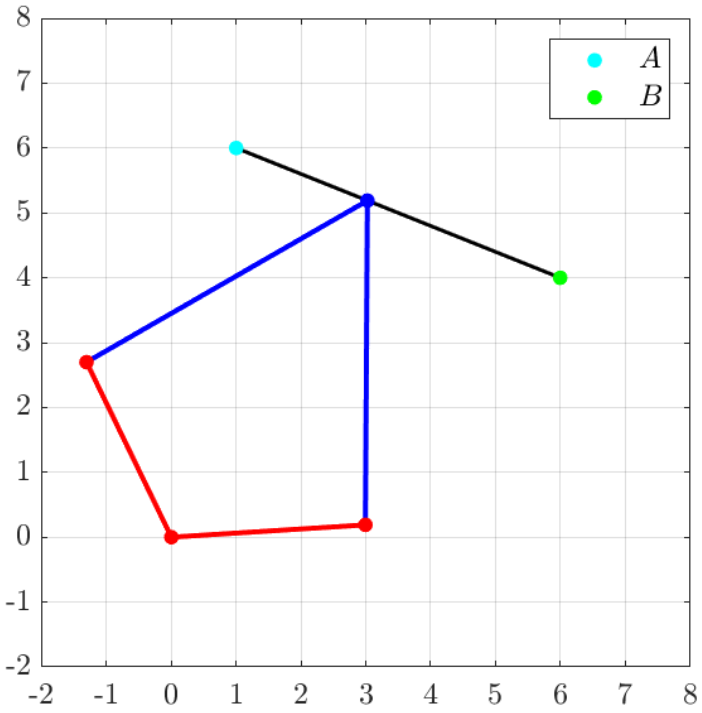
**a)** angles $\alpha$ and $\beta$ and their angular velocities and accelerations, when $P$ moves from $A$ to $B$ such that

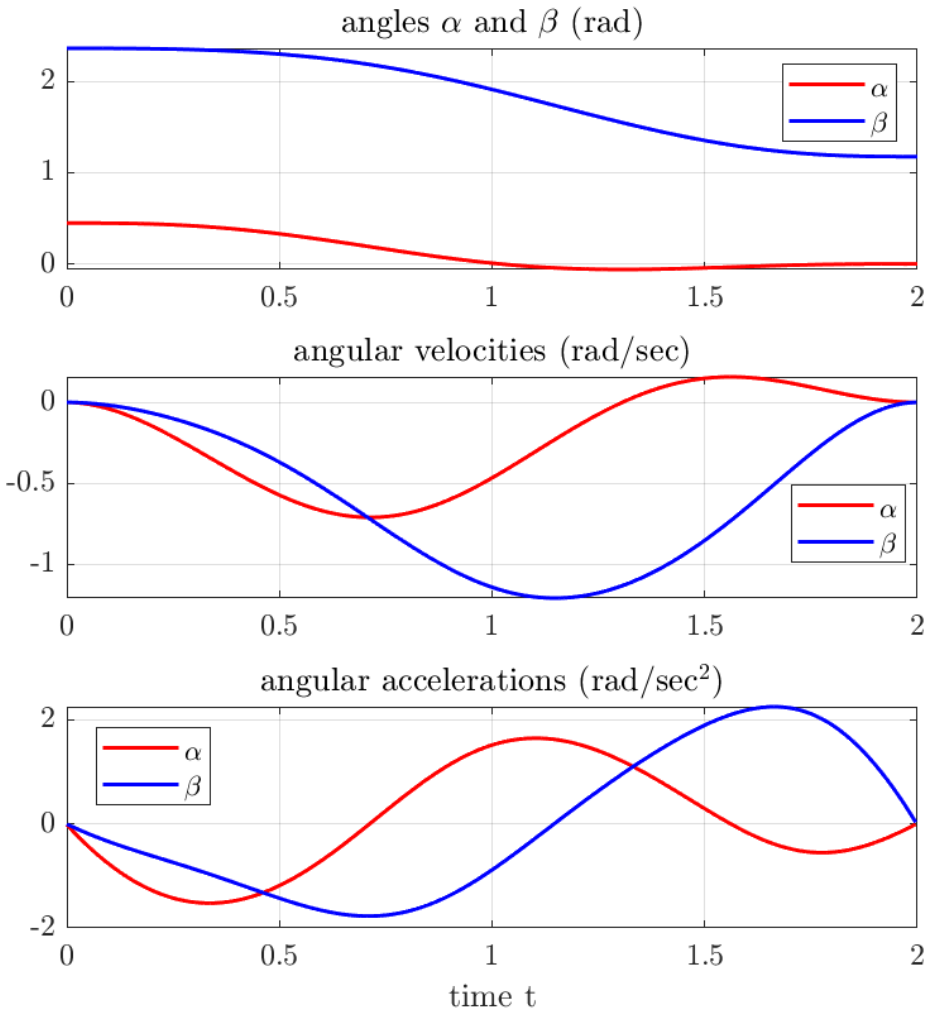
$$\begin{aligned} x(t) &= Ax + s(t) \cdot (Bx - Ax) \\ y(t) &= Ay + s(t) \cdot (By - Ay) \end{aligned}, \quad t = 0 \ldots T$$

where

$$s(t) = 6\left(\frac{t}{T}\right)^5 - 15\left(\frac{t}{T}\right)^4 + 10\left(\frac{t}{T}\right)^3$$

$R = 3, L = 5, T = 2$:


A
B


angles α and β (rad)
α
β
angular velocities (rad/sec)
α
β
angular accelerations (rad/sec²)
α
β
time t

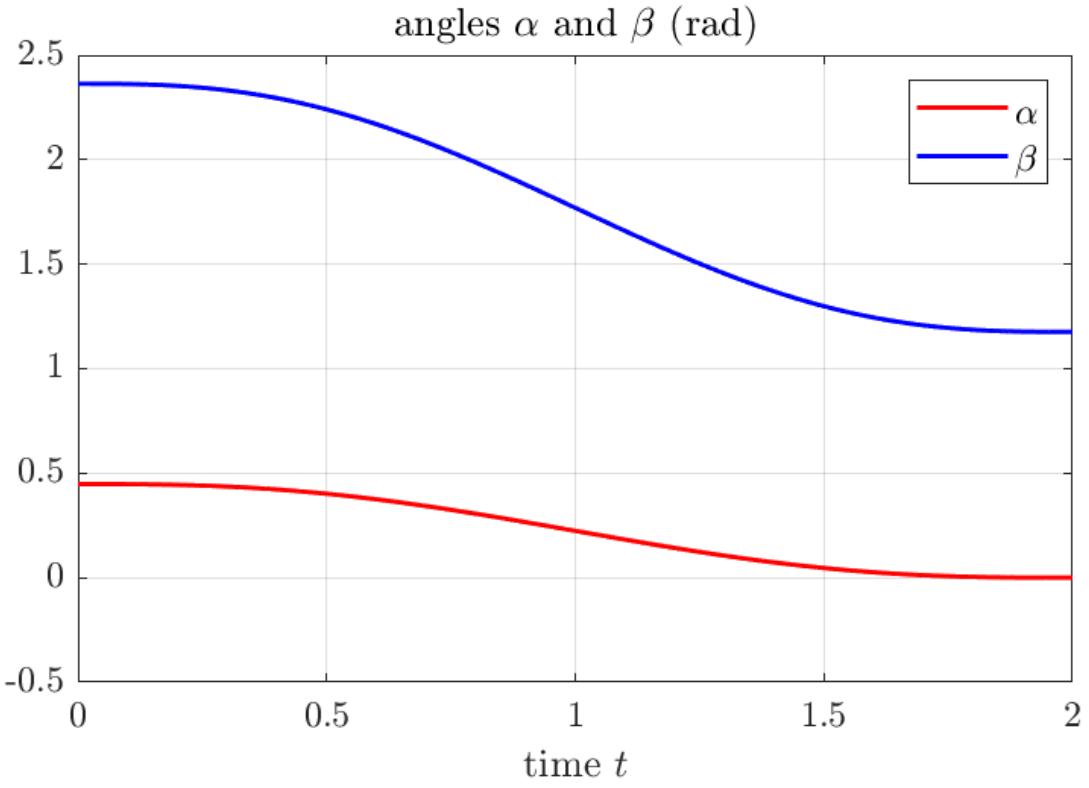
**b)** trajectory, velocity and acceleration of $P$, when it moves from $A$ to $B$ such that

$$\begin{aligned} \alpha(t) &= \alpha_A + s(t) \cdot (\alpha_B - \alpha_A) \\ \beta(t) &= \beta_A + s(t) \cdot (\beta_B - \beta_A) \end{aligned} \quad , \quad t = 0 \ldots T$$

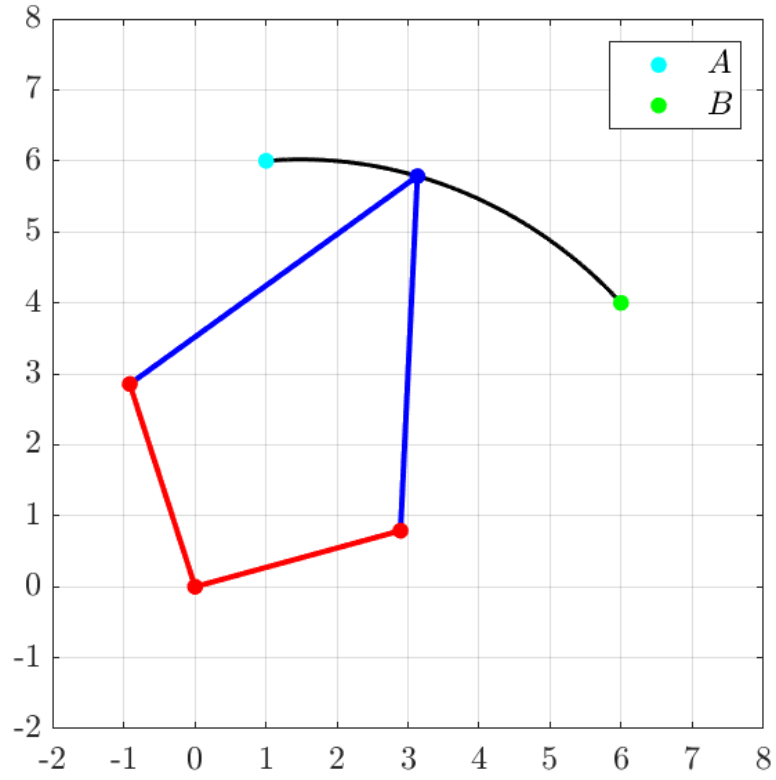
where

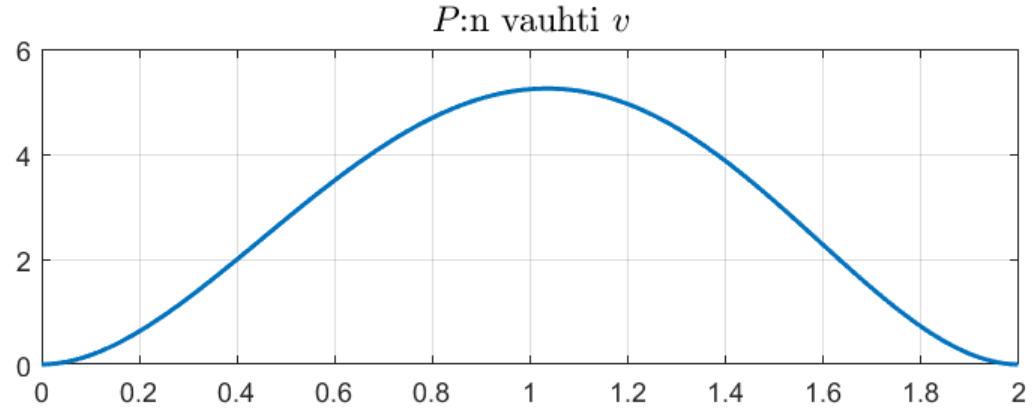
$$s(t) = 6\left(\frac{t}{T}\right)^5 - 15\left(\frac{t}{T}\right)^4 + 10\left(\frac{t}{T}\right)^3$$

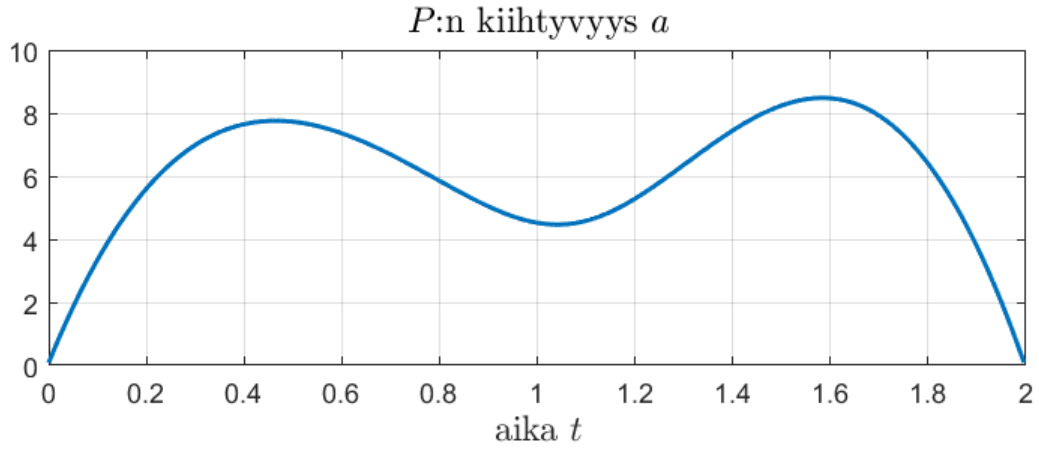
and $\alpha_A$, $\alpha_B$, $\beta_A$ and $\beta_B$ are the angles, when $P$ is at $A$ and $B$.



$R = 3, L = 5, T = 2$:


A
B
8
7
6
5
4
3
2
1
0
-1
-2
-2 -1 0 1 2 3 4 5 6 7 8


P:n vauhti v
6
4
2
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2


P:n kiihtyvyys a
10
8
6
4
2
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
aika t