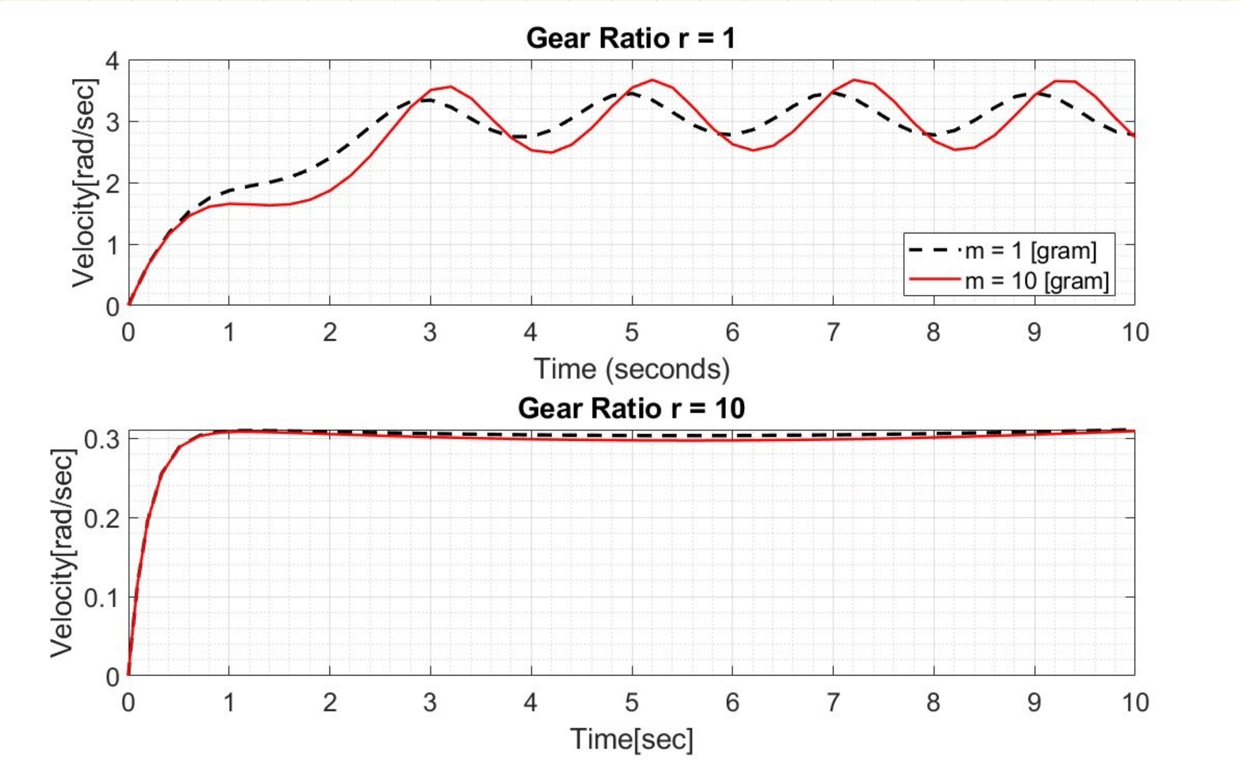
Promblem 1.

Rotary Electric Actuator



Linear Electric Actuator

Governing Equation:

$$\begin{cases} \text{KVL}: e_i = i R_m + K_m \dot{\theta}_m \\ \text{Torque balance}: J_m \ddot{\theta}_m + B_m \dot{\theta}_m + \frac{F \cdot p}{2\pi r} + \tau_{fric} = K_m i \end{cases}$$

Locked Rotor $\Rightarrow \dot{\theta}_m = 0$

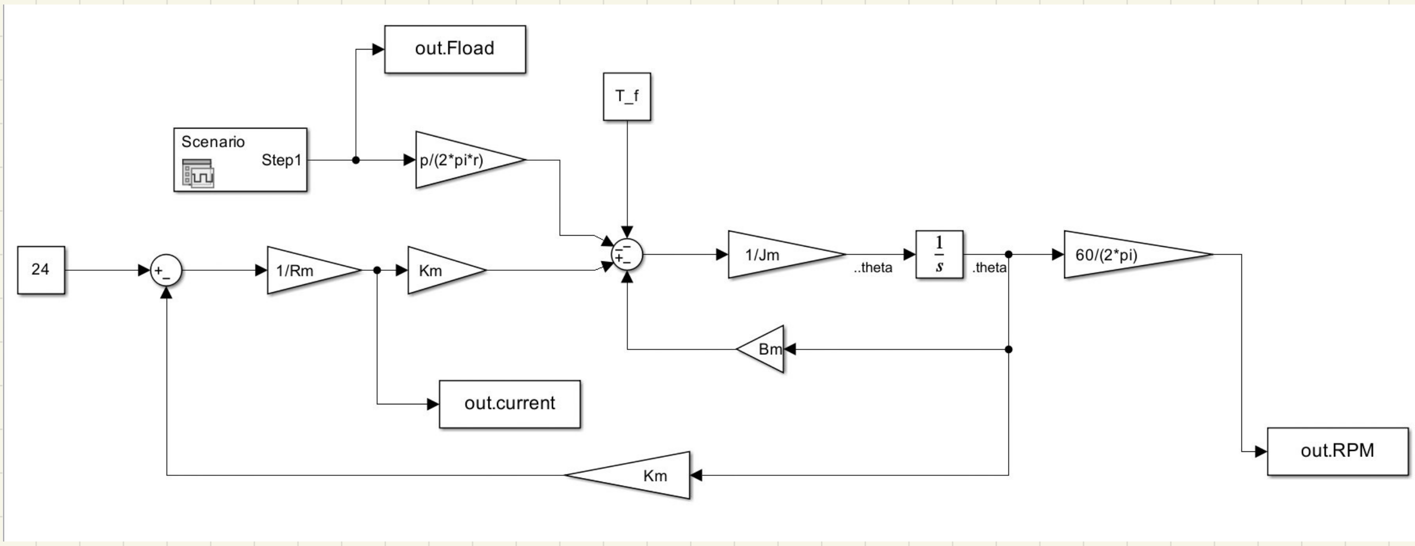
$24V = 5A \cdot R_m \Rightarrow R_m = 4.8$ ohms #

$$K_m = \frac{4000 \times (3\times10^{-3}) / (2\pi \cdot 6.25)}{5 - 0.35} = 0.066\,\text{Nm/A}$$ #

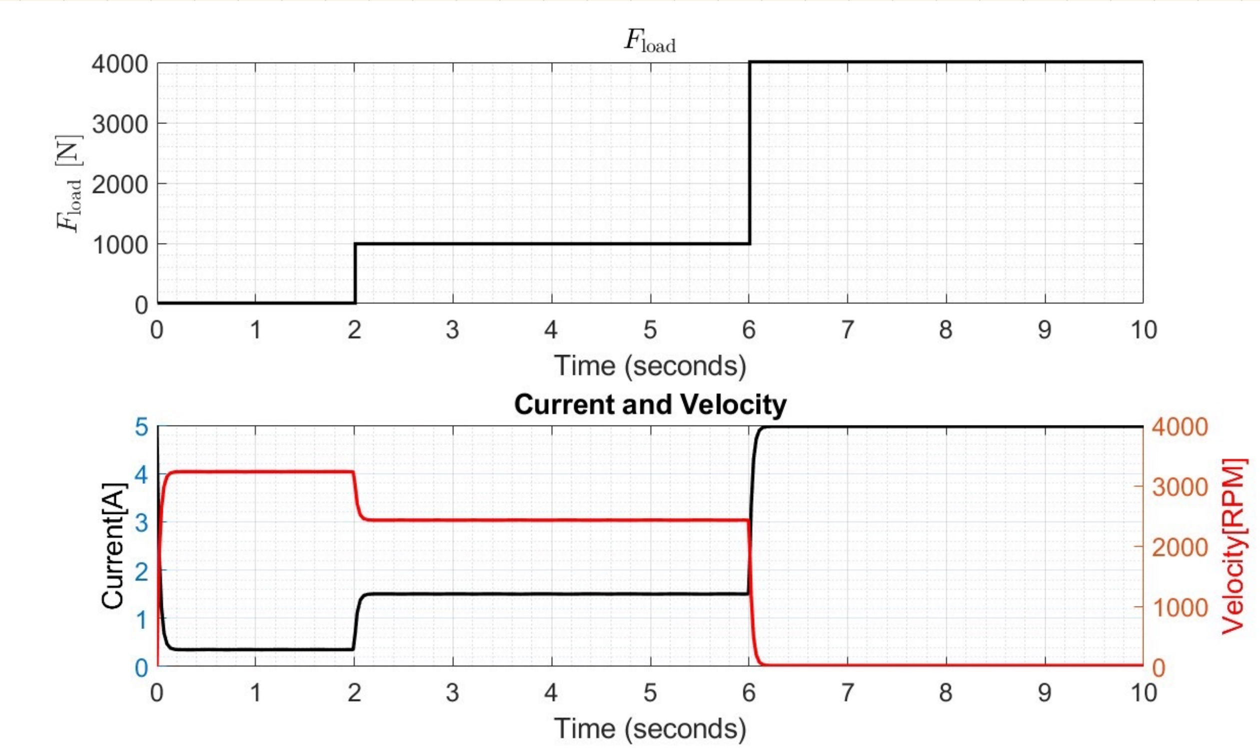
When no-load speed = 26 mm/s , $i = 0.35A$

$$B_m \dot{\theta}_m + \tau_{fric} = K_m i$$

$$\Rightarrow \tau_{fric} = 0.066 \cdot 0.35 - 10^{-8} \cdot \left(\frac{26}{3}\right) \cdot 6.25 = 0.023\,\text{Nm}$$ #



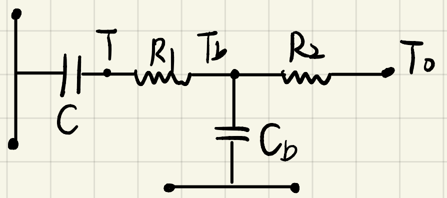
out.Fload
T_f
Scenario
Step1
p/(2*pi*r)
24
1/Rm
Km
1/Jm
..theta
1/s
.theta
60/(2*pi)
Bm
out.current
out.RPM
Km



F_{load}
F_{load} [N]
Time (seconds)
Current and Velocity
Current[A]
Velocity[RPM]
Time (seconds)

Problem 2.

Differential equation:



$$\begin{cases} C\dfrac{dT}{dt} = -\dfrac{T-T_b}{R_1} & ① \\ C_b\dfrac{dT_b}{dt} = \dfrac{T-T_b}{R_1} - \dfrac{T_b-T_o}{R_2} & ② \end{cases}$$

$\Rightarrow \mathcal{L}① \Rightarrow CsT(s) = -\frac{1}{R_1}(T(s)-T_b(s))$

$\Rightarrow T_b(s) = (CsR_1+1)T(s)$

$\Rightarrow \mathcal{L}② \Rightarrow C_b s T_b(s) = \frac{1}{R_1}(T(s)-T_b(s)) - \frac{1}{R_2}(T_b(s)-T_o(s))$

$C_b s(CsR_1+1)T(s) = -CsT(s) - \frac{(CsR_1+1)}{R_2}T(s) + \frac{T_o(s)}{R_2}$

$C_b s(CsR_1+1) + Cs + \frac{(CsR_1+1)}{R_2} \; T(s) = \frac{T_o(s)}{R_2}$

$$\Rightarrow \frac{T(s)}{T_o(s)} = \frac{1}{C_bCR_1R_2s^2 + (R_2C_b+R_2C+CR_1)s+1} \quad \#$$

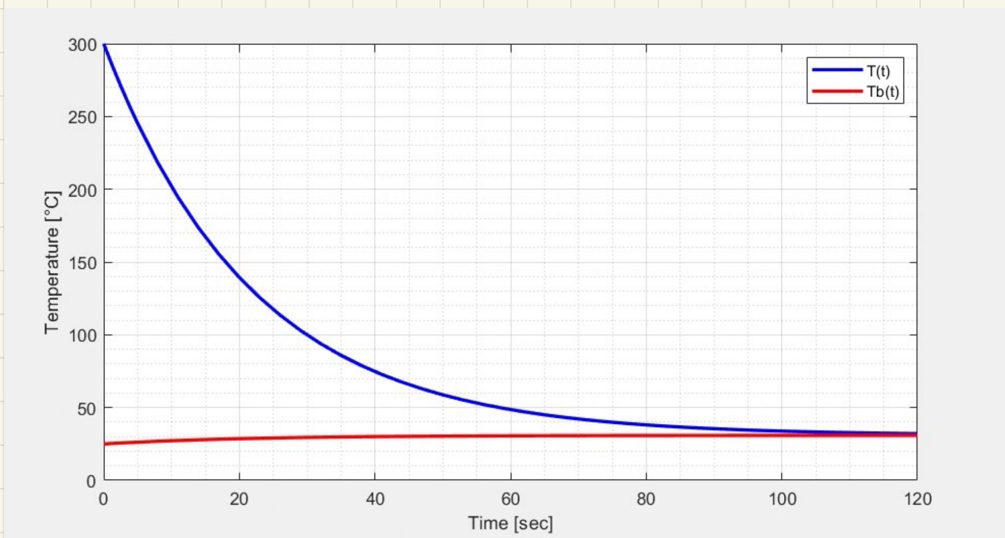
$$\text{poles} = \frac{-(R_2C_b+R_2C+R_1C) \pm \sqrt{(R_2C_b+R_2C+R_1C)^2 - 4C_bCR_1R_2}}{2C_bCR_1R_2}$$

If $(R_2C_b+R_2C+R_1C)^2 - 4C_bCR_1R_2 \geq 0$, the two poles are real

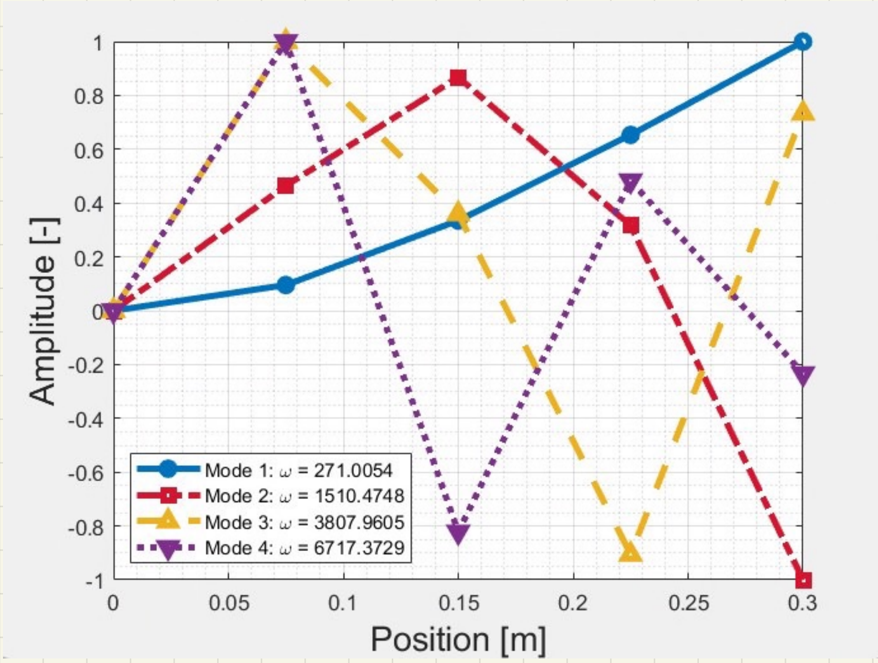
$$(R_2C_b+R_2C+R_1C)^2 - 4C_bCR_1R_2 = (R_2C_b)^2+(R_2C)^2+(R_1C)^2+2R_2^2CC_b+2R_1R_2C^2-2R_1R_2C_bC$$

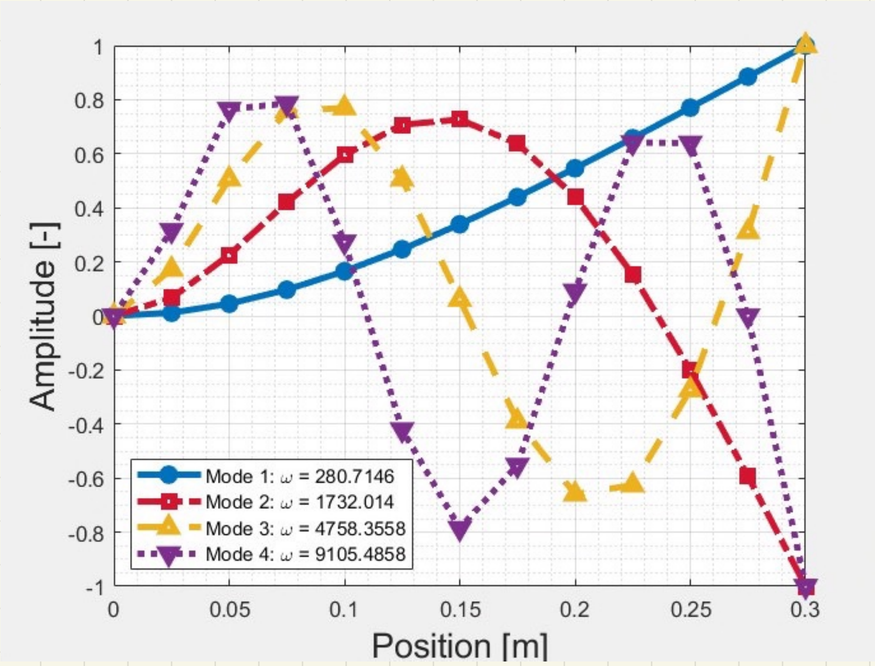
$$= (R_1C-R_2C_b)^2+(R_2C)^2+2R_2^2CC_b+2R_1R_2C^2 \geq 0$$

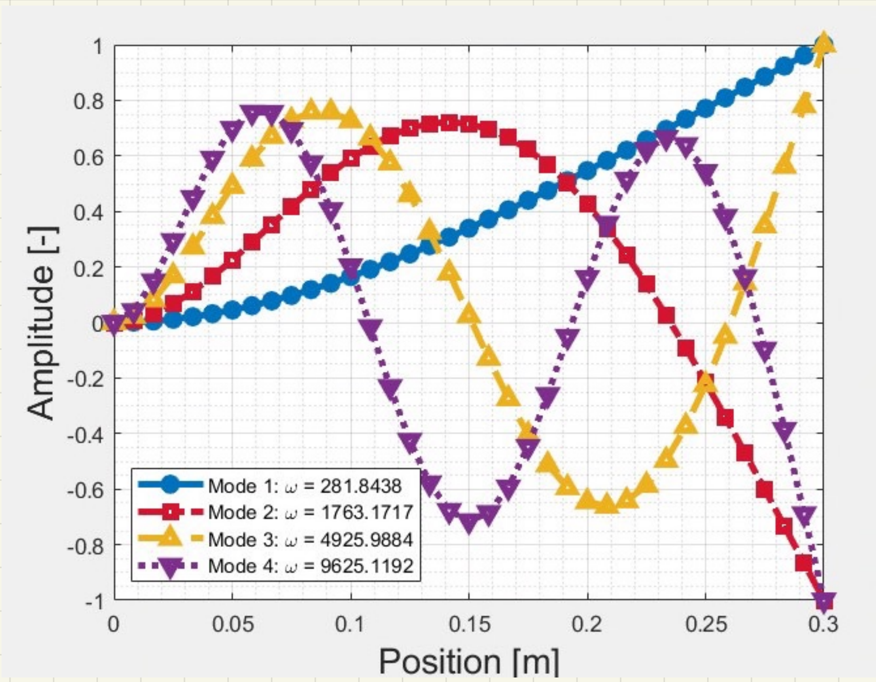
$\therefore$ the two poles are real.



Problem 3.


Amplitude [-]
Position [m]
Mode 1: ω = 271.0054
Mode 2: ω = 1510.4748
Mode 3: ω = 3807.9605
Mode 4: ω = 6717.3729


Amplitude [-]
Position [m]
Mode 1: ω = 280.7146
Mode 2: ω = 1732.014
Mode 3: ω = 4758.3558
Mode 4: ω = 9105.4858


Amplitude [-]
Position [m]
Mode 1: ω = 281.8438
Mode 2: ω = 1763.1717
Mode 3: ω = 4925.9884
Mode 4: ω = 9625.1192