UNIVERSITY MECHANICAL ENGINEERING • EXERCISE SHEET

# 12.2 Electromechanical systems

Name: _____ Class: _____ Date: _____ **Total: 16 marks**

**KEY WORDS** dc motor • back emf • mechanical time constant

## Objective

Find a dc motor's speed per volt, its time constants and stall values, then carry them through a gearbox to the load: top speed, holding voltage and the torque a current limit allows.

## 1 Key knowledge and worked examples

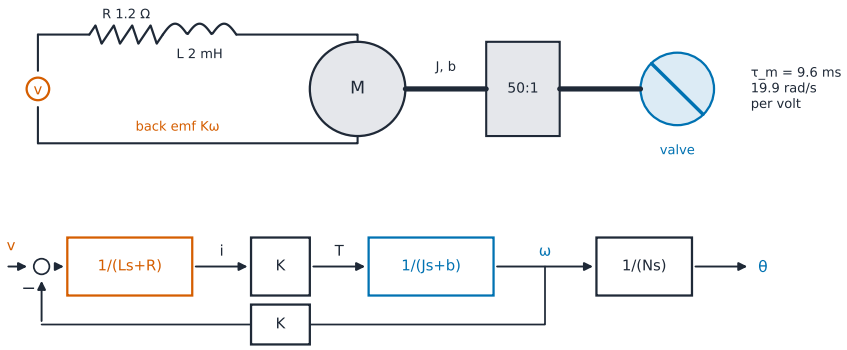
■ **Two constants join the circuit and the rotor**

- **DC motor** : torque $T = Ki$, **back emf** $e = K\omega$ (in SI, $K_t = K_e = K$).
- $\dfrac{\Omega}{V} = \dfrac{K}{(Js+b)(Ls+R)+K^2}$; with small $L$, gain $K/(bR+K^2)$ and **mechanical time constant** $\tau_m = JR/(bR+K^2)$; electrical $\tau_e = L/R$.
- Stall: $i = V/R$, $T = KV/R$.
- Through a gearbox $N$, efficiency $\eta$: speed $/N$; load torque at the motor $T_L/(N\eta)$.

■ **Worked example. The valve motor**

$R = 1.2\ \Omega$, $L = 2$ mH, $K = 0.05$ N · m/A, $J = 2 \times 10^{-5}$ kg · m$^2$, $b = 10^{-5}$ N · m · s/rad.

- Gain $= K/(bR+K^2) = 0.05/(1.2\times10^{-5}+0.0025) =$ **19.9** rad/s per volt; 12 V gives 239 rad/s.
- $\tau_m = JR/(bR+K^2) =$ **9.6** ms; $\tau_e = L/R = 1.7$ ms.
- Through $N = 50$: a 90° move takes at least **0.33** s.




## 2 Practice

A motor has $R = 2\ \Omega$, $L = 3$ mH, $K = 0.08$ N · m/A, $J = 5\times10^{-5}$ kg · m$^2$, $b = 2\times10^{-5}$ N · m · s/rad, on a 24 V supply.

**2.1** Find the steady speed per volt (two decimals, rad/s per V) and the no-load speed at 24 V (nearest rad/s). [3]

**2.2** Find $\tau_m$ (one decimal, ms) and $\tau_e$, and the stall current and torque. [4]

## 3 Exam-style questions

**3.1** The motor drives a valve through a $30:1$ gearbox with efficiency 0.85. The valve stem needs $8\ \mathrm{N\cdot m}$. (a) Find the motor torque, current and the voltage that just holds the valve (two decimals). (b) Find the valve's top speed with no load and under load at 24 V (two decimals, rad/s), and the shortest $90^\circ$ move under load (three decimals, s). (c) A 6 A current limit is set: find the valve torque it allows and the mechanical power at the motor shaft while moving under load. [9]