Solution Manual

System Dynamics

Modeling, Simulation and Control of Mechatronic Systems

5th Edition

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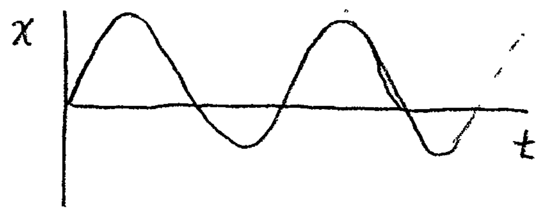
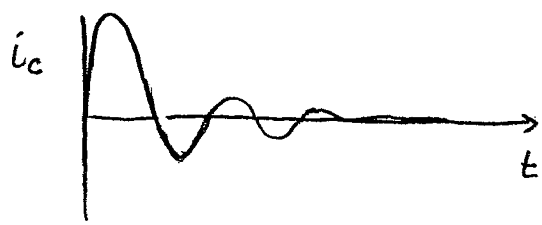
Problems 1.1 to 1.5 are mainly discussion questions.

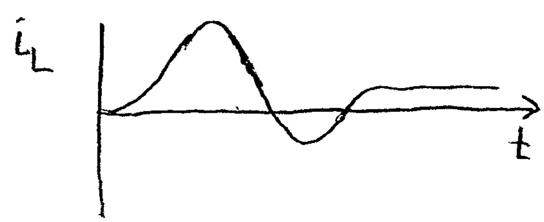
1.6



steady state deflection, $x_0 = \dfrac{(m+M)g}{k}$

1.7





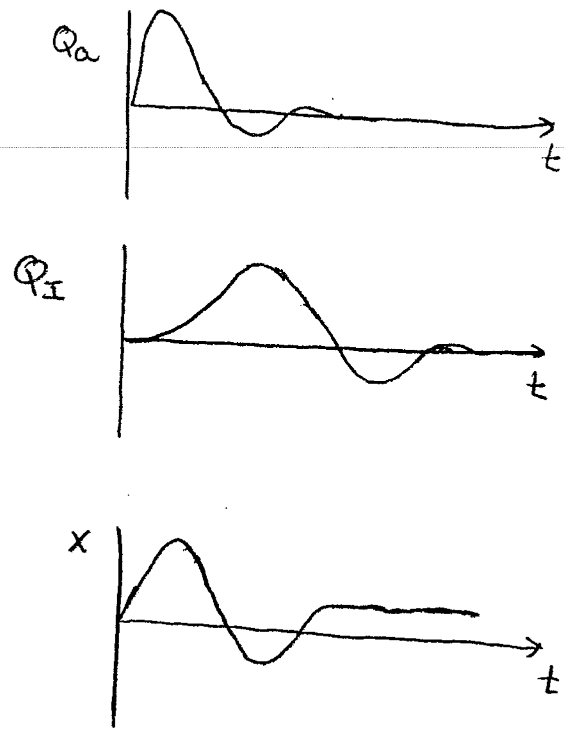
$i_{L_{ss}} = \dfrac{e_0}{R}$

1.8

$\left.\begin{array}{l} Q_a \text{ similar to } i_c \\ Q_I \text{ similar to } i_L \end{array}\right\}$ in prob. 1.7

$Q_{I_{ss}} = P_s / R_f$

1.9



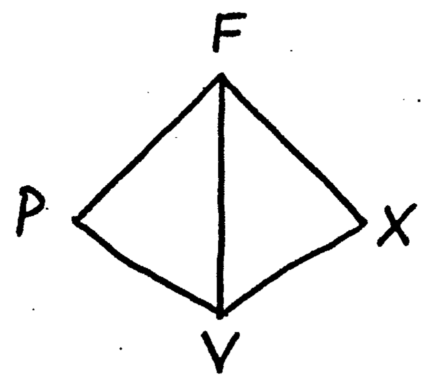
Accumulator

supply Pressure — pipe Tee — fluid line — cylinder — mass

spring

damper

2-1

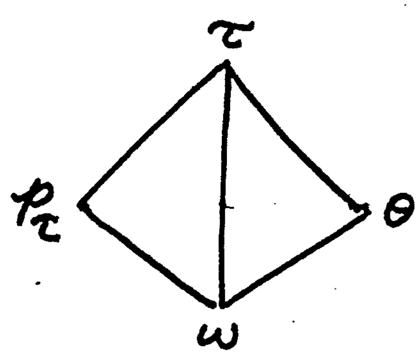


$[F]$ - N

$[V]$ - m/s

$[P]$ - N·s

$[X]$ - m

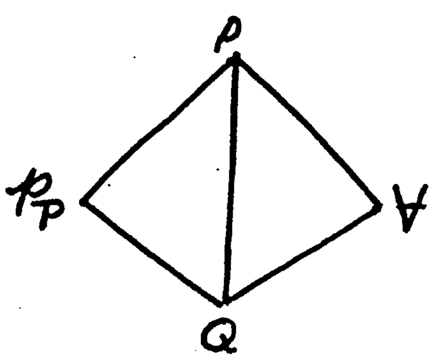


$[\tau]$ - N·m

$[\omega]$ - rad/s

$[p_\tau]$ - N·m·s

$[\theta]$ - rad

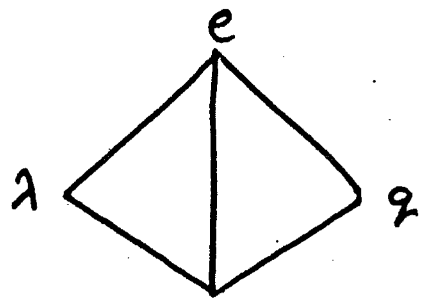


$[P]$ - N/m^2

$[Q]$ - m^3/s

$[p_P]$ - $N{\cdot}s/m^2$

$[\forall]$ - m^3



$[e]$ - V

$[i]$ - A

$[\lambda]$ - V·s

$[q]$ - A·s = C

2-2

$$\xrightarrow[\omega]{\tau} \text{Electric Motor} \xrightarrow[i]{e}$$

(a)

$$\xrightarrow[\omega]{\tau} \text{Hydraulic Pump} \xrightarrow[Q]{P}$$

(b)

$$\xleftarrow[\omega_1]{\tau} \text{Shaft} \xleftarrow[\omega_2]{\tau}$$

(c)

$$\xrightarrow[V_1]{F} \text{Shock Absorber} \xrightarrow[V_2]{F}$$

(d)

$$\xrightarrow[i_1]{e_1} \text{Transistor} \xrightarrow[i_2]{e_2}$$

(e)

$$\xrightarrow[i]{e} \text{Speaker}$$

(f)

$$\xrightarrow[\omega]{\tau} \text{Crank} \xrightarrow[V]{F}$$

(g)

$$\xrightarrow[V]{F} \text{Wheel} \xleftarrow[\omega]{\tau}$$

(h)

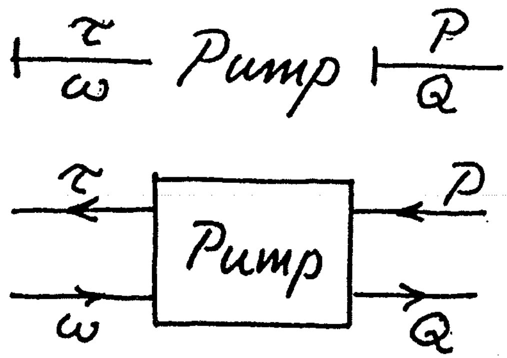
$$e_f \downarrow i_f$$

$$\xrightarrow[\omega]{\tau} \text{Motor} \xleftarrow[i_a]{e_a}$$

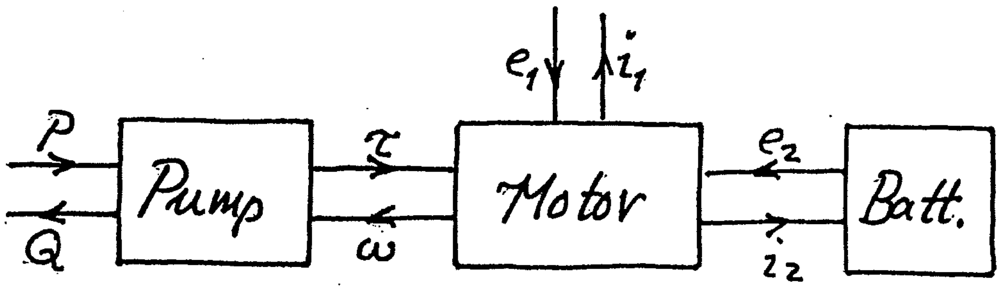
(i)

2-3

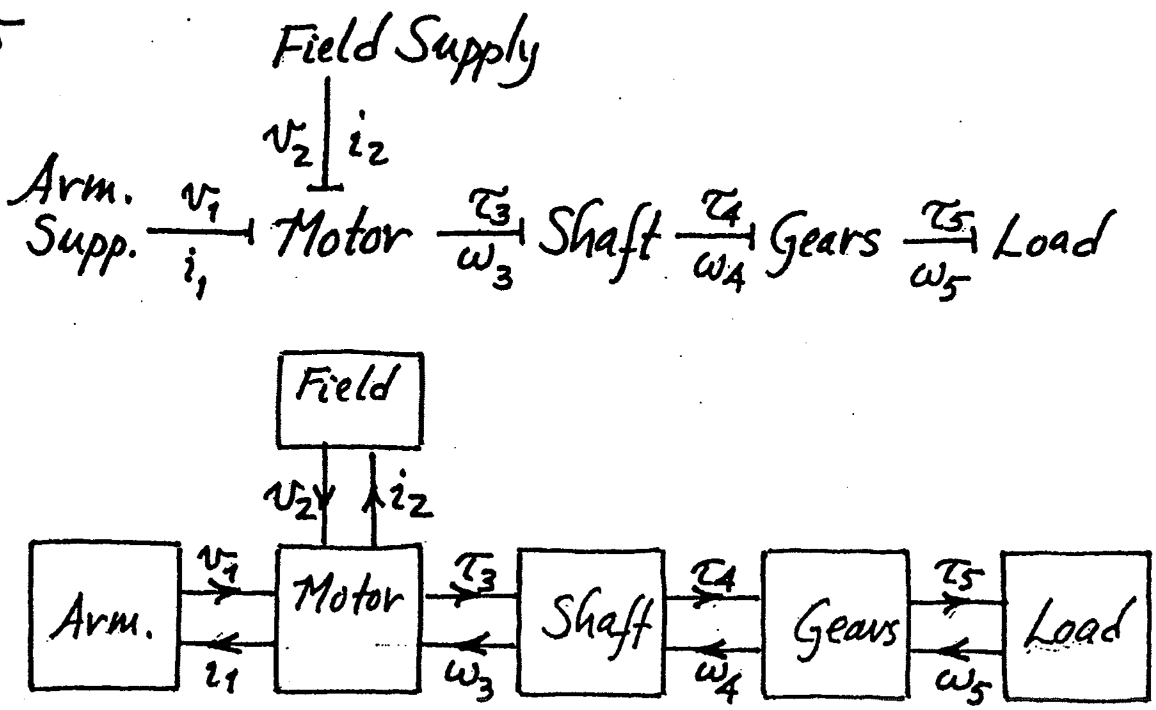
2-3


τ
ω
Pump
P
Q
τ
P
Pump
ω
Q

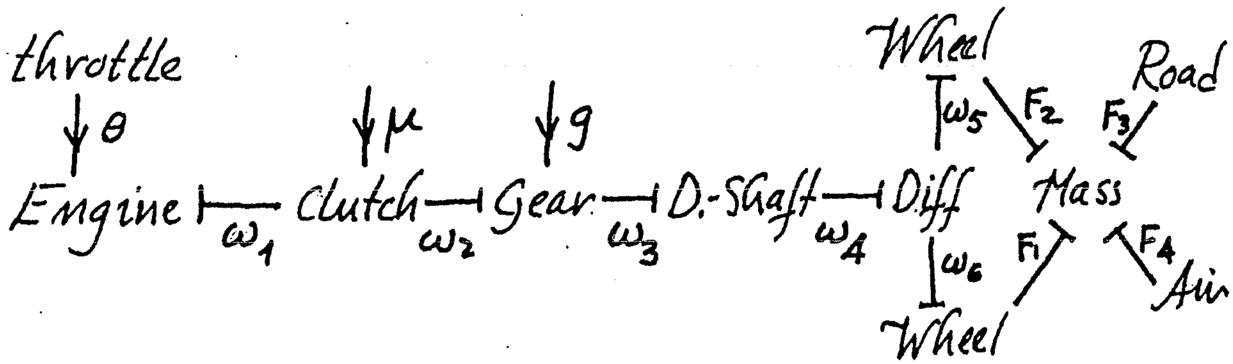
2-4

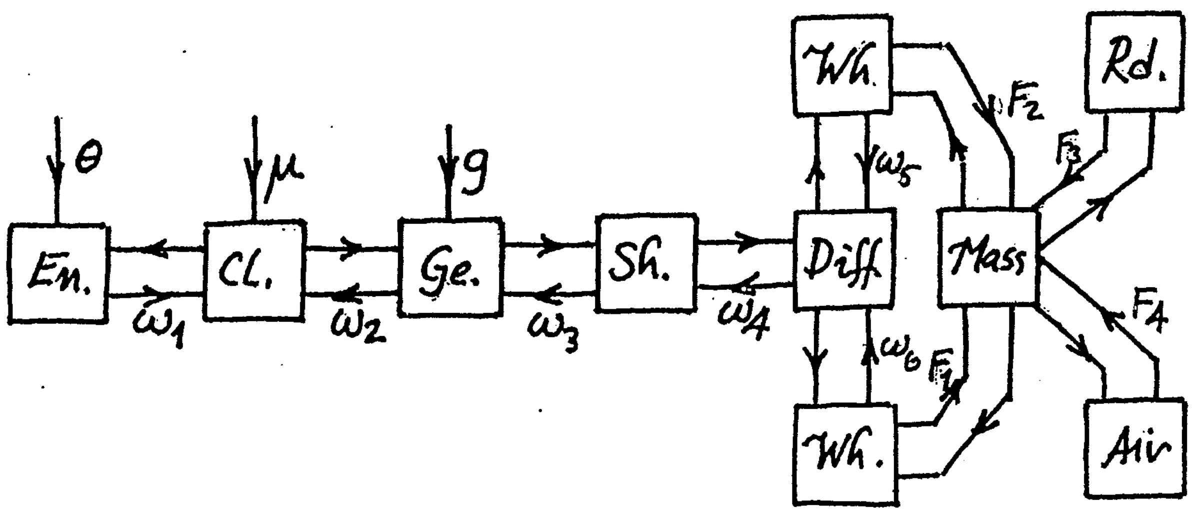

e1
i1
P
Pump
τ
Motor
e2
Batt.
Q
ω
i2

2-5


Field Supply
v2
i2
Arm. Supp.
v1
i1
Motor
τ3
ω3
Shaft
τ4
ω4
Gears
τ5
ω5
Load
Field
v2
i2
Arm.
v1
i1
Motor
τ3
ω3
Shaft
τ4
ω4
Gears
τ5
ω5
Load

2-6





2-7 Inputs: P, e_1, e_2

Outputs: Q, i_1, i_2

2-8

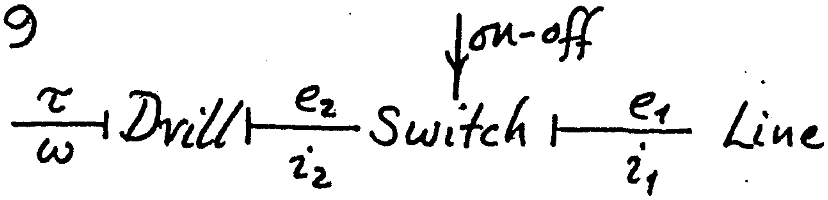
$$\text{Power} \times \text{Time} = \text{Energy}$$

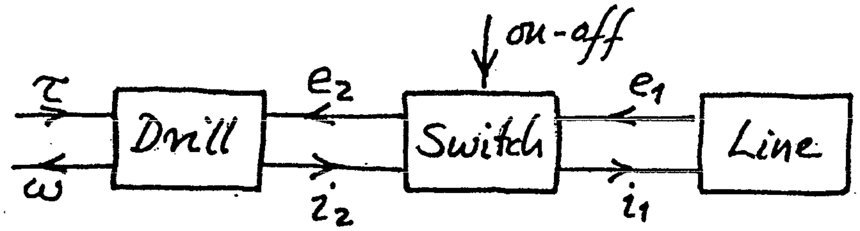
$$P \cdot t = mgh$$

$$100 \cdot t = 10 \cdot (9.81) \cdot 30$$

$$t = 29.43\ \text{s}$$

2-9





2-10 $\tau\omega = PQ$

$$\omega = \frac{P}{\tau} \cdot Q = \frac{7.0\times10^6}{5} Q$$

$$\omega = 1.4\times10^6 Q$$

$$\left[\frac{rad}{s}\right] = \left[\frac{1}{m^3}\right]\cdot\left[\frac{m^3}{s}\right]$$

2.11 using kinematics:

$$x = R\cos\theta + l\cos\alpha$$

$$l\sin\alpha = R\sin\theta$$

$$\cos\alpha = \sqrt{1-\sin^2\alpha} = \sqrt{1-\frac{R^2}{l^2}\sin^2\theta}$$

$$\therefore \quad x = R\cos\theta + l\sqrt{1-\frac{R^2}{l^2}\sin^2\theta}$$

Then

$$\dot{x} = -v = -R\sin\theta\,\dot{\theta} + l\,\frac{1}{2}\left[1-\frac{R^2}{l^2}\sin^2\theta\right]^{-1/2}\left(-\frac{R^2}{l^2}\,2\sin\theta\cos\theta\right)\dot{\theta}$$

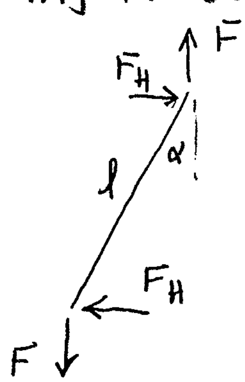
or

$$v = \underbrace{\left[R\sin\theta + \frac{l\left(\frac{R}{l}\right)^2\sin\theta\cos\theta}{\sqrt{1-\left(\frac{R}{l}\right)^2\sin^2\theta}}\right]}_{m(\theta)}\dot{\theta}$$

$$\therefore \quad v = m(\theta)\,\omega$$

$$T = m(\theta)\,F$$

using Forces and moments:

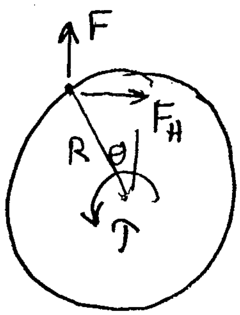


moment equilibrium for rod:

$$F\,l\sin\alpha = F_H\,l\cos\alpha$$

or

$$F_H = F\sin\alpha/\cos\alpha$$



moment equilibrium for crank:

$$T = F_H R\cos\theta + F R\sin\theta$$

$$= F\frac{\sin\alpha}{\cos\alpha}R\cos\theta + F R\sin\theta$$

use $\sin\alpha = \frac{R}{l}\sin\theta$

$$\cos\alpha = \sqrt{1-\left(\frac{R}{l}\right)^2\sin\theta}$$

substitute and you will end up with:

$$T = m(\theta)\,F$$

2.12

element	inputs	outputs
supply pressure	Q_s	P_s
Tube	P_s, P_a, Q_ℓ	Q_s, Q_a, P_c
Accumulator	Q_a	P_a
Cylinder	P_c, v_m	Q_ℓ, F_m
Mass	F_m, F_s, F_d	v_m, v_s, v_d
Spring	v_s	F_s
Damper	v_d	F_d