

Solution Manual

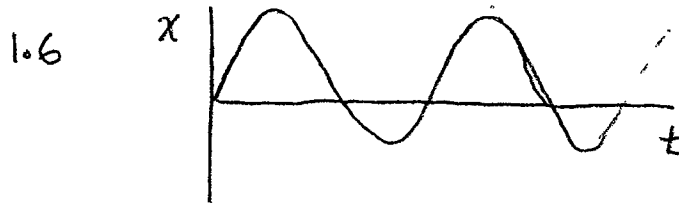
System Dynamics

**Modeling, Simulation and Control of
Mechatronic Systems**

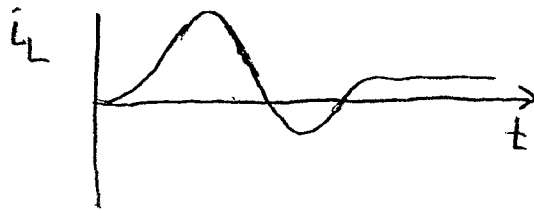
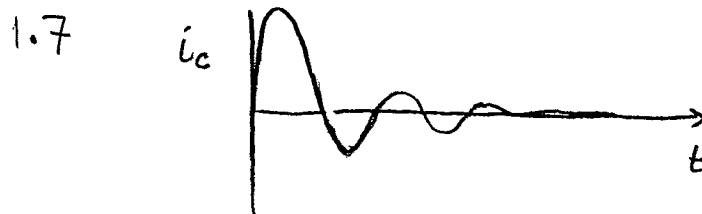
5th Edition

**Dean C. Karnopp
Donald L. Margolis
Ronald C. Rosenberg**

Problems 1.1 to 1.5 are mainly discussion questions.



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



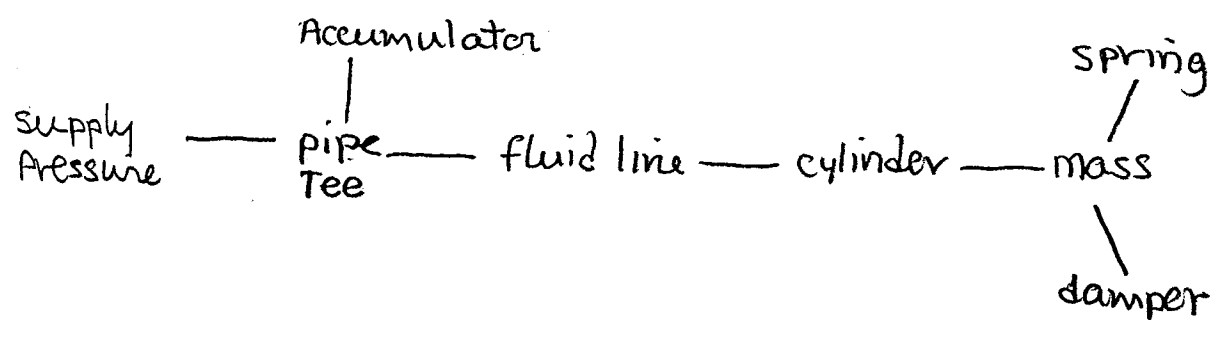
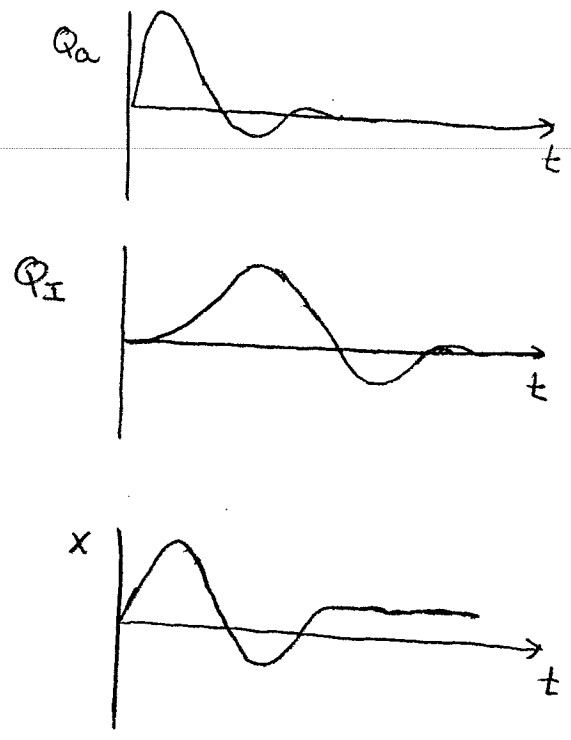
$$i_{L_{ss}} = \frac{E_0}{R}$$

1.8 $\left. \begin{array}{l} Q_a \text{ similar to } \dot{i}_c \\ Q_I \text{ similar to } \dot{i}_L \end{array} \right\} \text{ in prob. 1.7}$

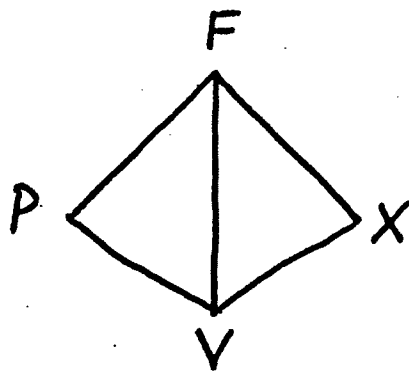
$$Q_{I_{ss}} = P_s / R_f$$

1.9

1-2



2-1

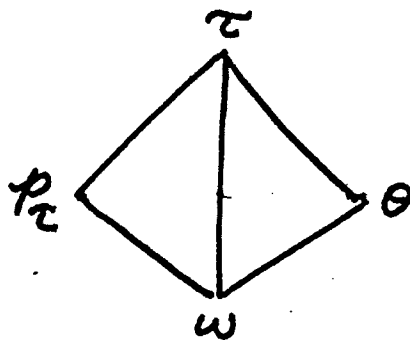


$$[F] - N$$

$$[Y] - m/s$$

$$[P] - N \cdot s$$

$$[X] - m$$

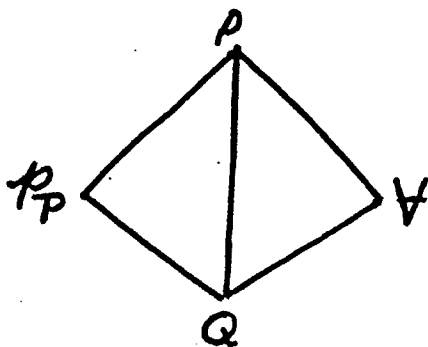


$$[z] - N \cdot m$$

$$[w] - rad/s$$

$$[p_z] - N \cdot m \cdot s$$

$$[\theta] - rad$$

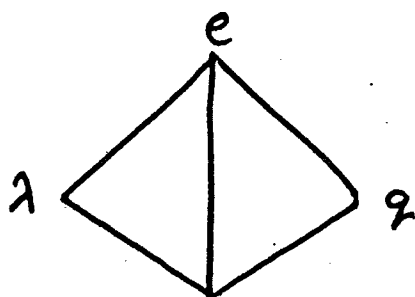


$$[P] - N/m^2$$

$$[Q] - m^3/s$$

$$[p_p] - N \cdot s/m^2$$

$$[v] - m^2$$



$$[e] - V$$

$$[i] - A$$

$$[\lambda] - V \cdot s$$

$$[q] - A \cdot s = C$$

2-2

$$\frac{\tau}{\omega} \text{ Electric Motor } \frac{e}{i}$$

2-2

(a)

$$\frac{\tau}{\omega} \text{ Hydraulic Pump } \frac{P}{Q}$$

(b)

$$\frac{\tau}{\omega_1} \text{ Shaft } \frac{\tau}{\omega_2}$$

(c)

$$\frac{F}{V_1} \text{ Shock Absorber } \frac{F}{V_2}$$

(d)

$$\frac{e_1}{i_1} \text{ Transistor } \frac{e_2}{i_2}$$

(e)

$$\frac{e}{i} \text{ Speaker}$$

(f)

$$\frac{\tau}{\omega} \text{ Crank } \frac{F}{V}$$

(g)

$$\frac{F}{V} \text{ Wheel } \frac{\tau}{\omega}$$

(h)

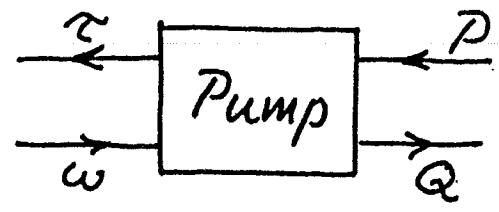
$$\frac{\tau}{\omega} \text{ Motor } \frac{e_a}{i_a} \quad e_f / i_f$$

(i)

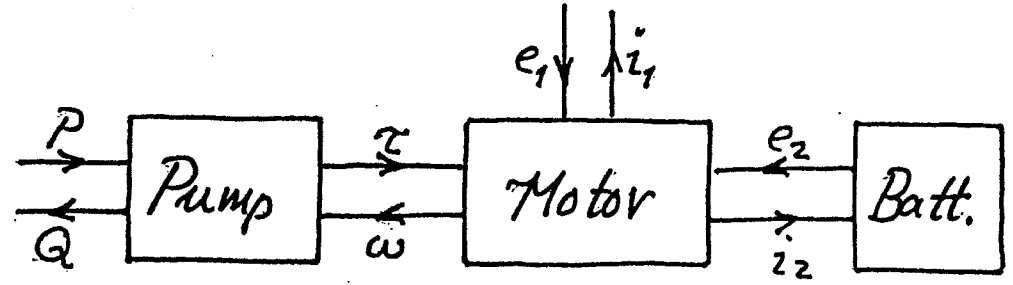
2-3



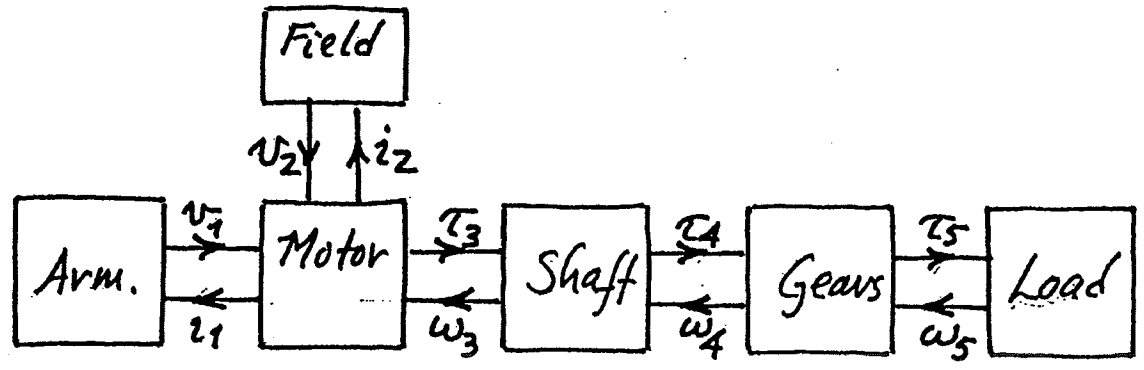
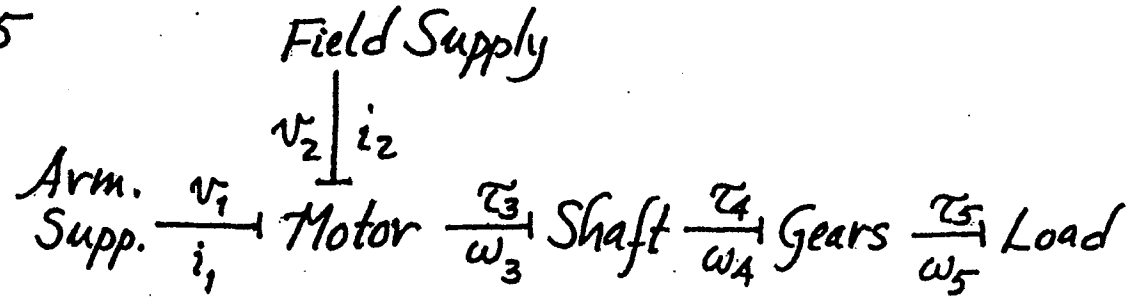
2-3



2-4

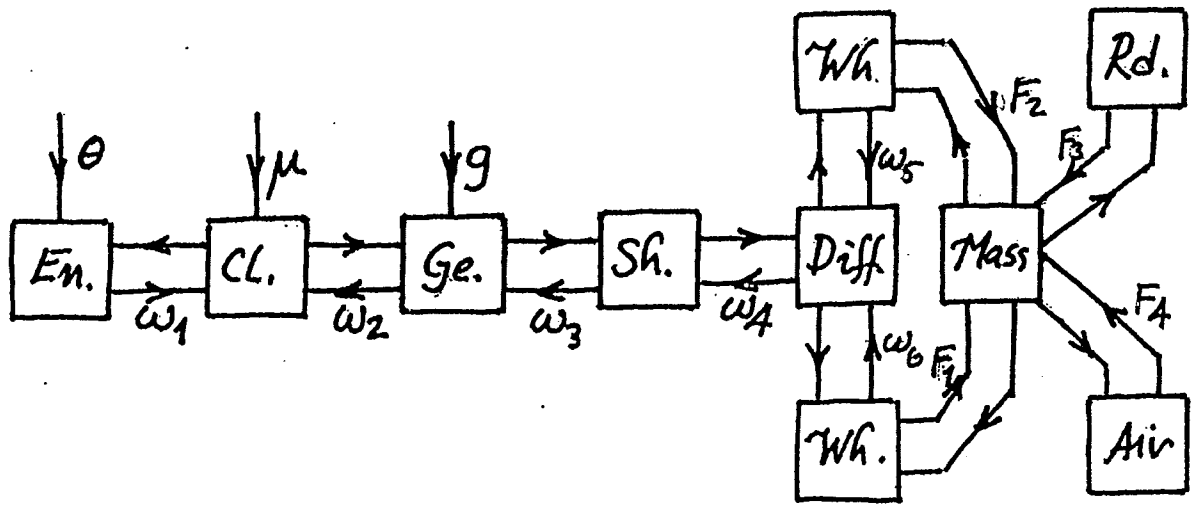
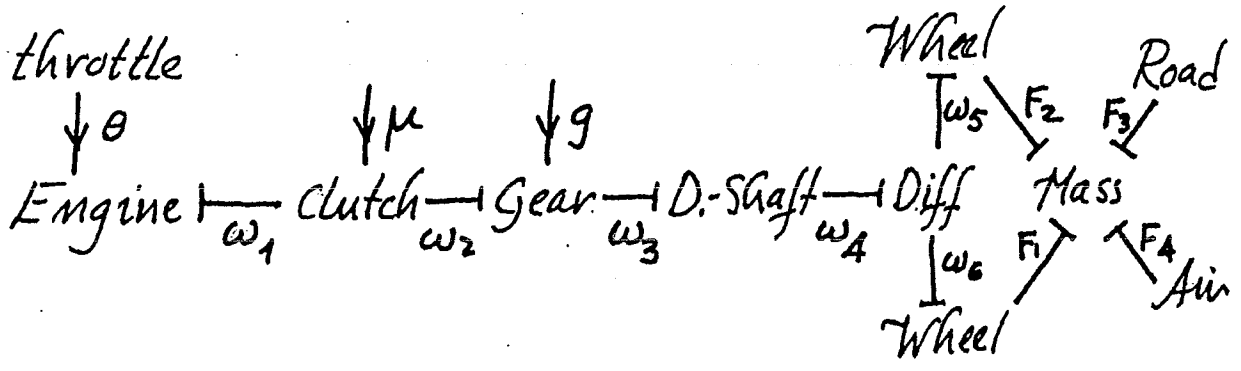


2-5



2-6

2-4



2-7 Inputs: P, e_1, e_2

Outputs: Q, i_1, i_2

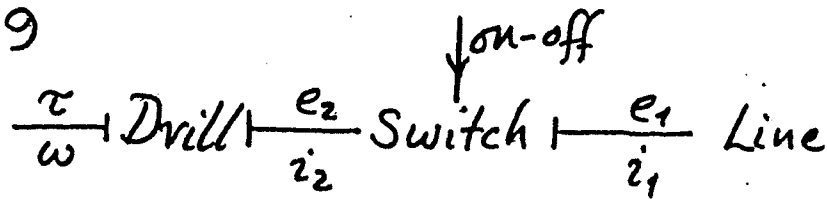
2-8

Power \times Time = Energy
 $P \cdot t = mgh$

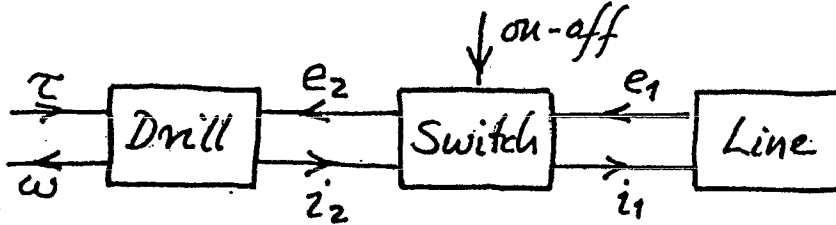
$100 \cdot t = 10 \cdot (9.81) \cdot 30$

$t = 29.43 \text{ s}$

2-9



2-5



2-10

$$\tau\omega = PQ$$

$$\omega = \frac{P}{\tau} \cdot Q = \frac{7.0 \times 10^6}{5} Q$$

$$\omega = 1.4 \times 10^6 Q$$

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

2.11

using kinematics:

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

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

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

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

Then

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

or

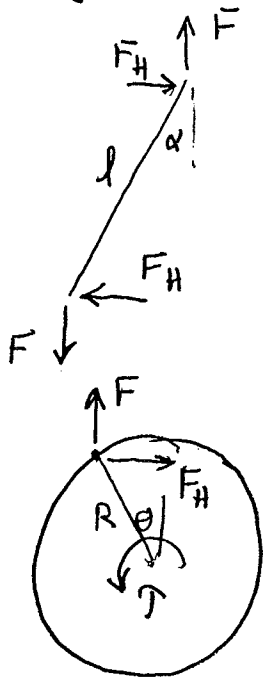
$$v = \left[R \sin \theta + l \frac{\left(\frac{R}{l}\right)^2 \sin \theta \cos \theta}{\sqrt{1 - \left(\frac{R}{l}\right)^2 \sin^2 \theta}} \right] \dot{\theta}$$

$m(\theta)$

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

$$\tau = m(\theta) F$$

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:

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

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

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

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

substitute and you will
end up with:

$$\tau = m(\theta) F$$

2.12

element	inputs	outputs
supply pressure	Q_s	P_s
Tube	P_s, P_a, Q_e	Q_s, Q_a, P_c
Accumulator	Q_a	P_a
Cylinder	P_c, v_m	Q_e, 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