

Chapter 2

P2-1

Problem	Element	Parameter	Element Type	Energy
(a)	4 Springs	k	C-elements	Potential
	2 Masses	m	I-elements	Kinetic
	Velocity Source	$v(t)$	Flow source	Supplies
(b)	1 Spring	k	C-element	Potential
	2 Dampers	b_1, b_2	R-elements	Dissipate
	2 Masses	m	I-elements	Kinetic
	External Force	$F(t)$	Effort source	Supplies
(c)	1 Spring	k	C-element	Potential
	1 Damper	b	R-element	Dissipate
	1 Mass	m	I-element	Kinetic
	External Force	$F(t)$	Effort source	Supplies
(d)	2 Springs	k_1, k_2	C-elements	Potential
	2 Masses	m_1, m_2	I-elements	Kinetic
	2 Dampers	b_1, b_2	R-elements	Dissipate
	External Force	$F(t)$	Effort source	Supplies

P2-2

Problem	Element	Parameter	Element Type	Energy
(a)	External Moment	τ_m	Effort source	Supplies
	Bearings	$\beta_1, \beta_2, \beta_3$	R-elements	Dissipate
	Shaft	κ	C-element	Potential
	Rotational Inertia	J	I-element	Kinetic
	Gear Pair	N_1/N_2	Transformer	Converts
(b)	External Moment	τ_m	Effort source	Supplies
	4 Bearings and Friction	β, β_{fric}	R-elements	Dissipate
	2 Shafts	κ	C-element	Potential
	2 Rotational Inertias	J	I-element	Kinetic
	2 Gear Pairs	$N_1/N_2, N_3/N_4$	Transformer	Converts
(c)	2 External Moments	τ_1, τ_2	Effort source	Supplies
	3 Shafts	$\kappa_1, \kappa_2, \kappa_3$	C-elements	Potential
	6 Bearings	$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$	R-elements	Dissipate
	4 Rotational Inertias	J_1, J_2, J_3, J_4	I-elements	Kinetic

P2-3

Problem	Element	Parameter	Element Type	Energy
(a)	Battery	$e(t)$	Effort source	Supplies
	2 Resistors	R_1, R_2	R-elements	Dissipate
	1 Capacitor	C	C-element	Potential
	1 Inductor	L	I-element	Kinetic
(b)	Voltage Source	$e(t)$	Effort source	Supplies
	1 Inductor	L	I-element	Kinetic
	1 Resistor	R	R-element	Dissipate
	1 Capacitor	C	C-element	Potential
	1 Transformer	N_1/N_2	Transformer	Converts
(c)	Voltage Source	$e(t)$	Effort source	Supplies
	2 Inductors	L_1, L_2	I-elements	Kinetic
	1 Resistor	R	R-element	Dissipate
	1 Capacitor	C	C-element	Potential
	1 Transformer	N_1/N_2	Transformer	Converts
	Current Source	$i(t)$	Flow source	Supplies

P2-4

Problem	Element	Parameter	Element Type	Energy
(a)	Flow Source	Q	Flow source	Supplies
	2 Accumulators	C_1, C_2	R-elements	Dissipate
	2 Valves	R_1, R_2	C-element	Potential
	Pipe	I_f	I-element	Kinetic
(b)	2 Flow Sources	Q	Flow source	Supplies
	2 Accumulators	C_1, C_2	R-elements	Dissipate
	2 Valves	R_1, R_2	C-element	Potential
(c)	Pressure Source	P_{in}	Effort source	Supplies
	3 Valves	R_1, R_2, R_3	R-elements	Dissipate
	2 Accumulators	C_1, C_2	R-elements	Dissipate
	Pipe	I_f, R_f	I- and R-elements	Kinetic and Dissipate

P2-5

Element	Parameter	Element Type	Energy
Voltage Source	$e_{in}(t)$	effort source	Supplies
1 Inductor	L	I-element	Kinetic
1 Resistor	R	R-element	Dissipate
Ideal Motor	k_m	Gyrator	Converts
1 Rotational Inertia	J	I-element	Kinetic
Gear Pair	N_1/N_2	Transformer	Converts
1 Bearing	β	R-element	Dissipate

P2-6

$$mL^2\ddot{\theta} \approx -mgL\theta + \tau(t)$$

P2-7

$$f(x) \approx f(\hat{x}) + \left. \frac{\partial f}{\partial x} \right|_{\hat{x}} (x - \hat{x})$$

$$\begin{aligned} F_{fric} \approx & \left[F_k + \left(F_s - F_k e^{-c_v |v_o|} \right) \right] \frac{v}{|v_o|} + b v_o \\ & + \left[b + \frac{F_k - e^{-c_v |v|} F_k + F_s}{|v|} \right. \\ & - \frac{(f_k - e^{-c_v |v|} F_k + F_s) v^2 / |v|}{|v|^2} \\ & \left. + \frac{c_v e^{-c_v |v|} F_k v^2 / |v|}{|v|} \right] (v - v_o) \end{aligned}$$

P2-8

$$f(x) \approx f(\hat{x}) + \left. \frac{\partial f}{\partial x} \right|_{\hat{x}} (x - \hat{x})$$

$$Q(\Delta P) \approx K \sqrt{\Delta P_o} + \frac{K}{2 \sqrt{\Delta P_o}} \Delta P$$