SUMMARY OF EFFORT AND FLOW RELATIONSHIPS
ENBE 471

Power Variables

Energy Domain	Effort (e) (Generally expressed as a gradient)	Flow (f)
Electrical	Voltage (v)	Current (i)
Rotational Mechanics	Torque (τ)	Angular Velocity (ω)
Translational Mechanics	Force (F)	Velocity (v)
Hydraulic Circuits	Pressure (P)	Volume Flow Rate (Q)
Thermal	Temperature (T)	Entropy Flow Rate (S)
Chemical Diffusion	Chemical Potential (μ)	Molar Flow Rate (n)

Some Useful Alternate Units

Thermal	Temperature (T)	Heat Flow Rate (q)
Diffusion	Concentration (C)	Molar or Mass Flow Rate (n)

Storage Elements (accumulate either effort or flow)

Energy Domain	$\int$ effort (Momentum)	$\int$ flow (Displacement)
General Formula	$\int_0^t e\,dt$	$\int_0^t f\,dt$
Rotational Mechanics	Angular Momentum (h)	Angular Displacement (ω)
Translational Mechanics	Momentum (P)	Displacement (y)
Hydraulics	Pressure Momentum (γ)	Volume (V)
Thermal	—	Entropy (S) – Power Energy (H) – Alternate
Chemical	—	Moles (n)

Elements

Element	**Effort**	**Flow**	**Relation Type**
Resistance	$e = e(f)$	$f = f(e)$	Nonlinear
e.g. Resistance, Damping Factor Fluid Resistance Thermal Resistance	$e = Rf$	$f = \frac{e}{R} = Ge$	Linear
Capacitance (Integrated Flow Element)	$e = e(q)$ or $e = e\left(\int_0^t f\,dt\right)$	$f = \frac{dq}{dt}$ or $f = \frac{dq(e)}{dt}$	Nonlinear
e.g. Capacitance Thermal Capacitance Fluid Capacitance Spring Constant Compliance	$e = \frac{q}{C}$ or $e = \frac{\int_0^t f\,dt}{C}$	$f = \frac{dq}{dt}$ or $f = \frac{dCe}{dt}$ or $f = C\frac{de}{dt}$	Linear
Inertance (Integrated Effort Element)	$e = \frac{dp}{dt}$ or $e = \frac{dp(f)}{dt}$	$f = f(p)$ or $f = f\left(\int_0^t e\,dt\right)$	Nonlinear
p = momentum I = Inertance Inductance Fluid Inertia	$e = \frac{dp}{dt}$ or $e = \frac{dIf}{dt}$ or $e = I\frac{df}{dt}$ or $e = I\ddot{q}$	$f = \frac{p}{I}$ or $f = \frac{\int_0^t e\,dt}{I}$	Linear

Connectors

Element	**Effort**	**Flow**	**Relation Type**
Transformer m = modulus of the transformer	$e_1 = m(e_2)$	$f_2 = m(f_1)$	Nonlinear
	$e_1 = m\ e_2$	$f_2 = m\ f_1$	Linear
Gyrator r = modulus of the gyrator	$e_1 = r(f_2)$ or $e_2 = r(f_1)$	$f_1 = \frac{1}{r}(e_2)$ or $f_2 = \frac{1}{r}(e_1)$	Nonlinear
	$e_1 = r\ f_2$ or $e_2 = r\ f_1$	$f_1 = \frac{e_2}{r}$ or $f_2 = \frac{e_1}{r}$	Linear
Common Effort Junction	$e_1 = e_2 = e_3 = e_4 = \ldots$	$\sum f = 0$	
Common Flow Junction	$\sum e = 0$	$f_1 = f_2 = f_3 = f_4 = \ldots$	