Mechanical System Modeling and Coupling Mechanisms

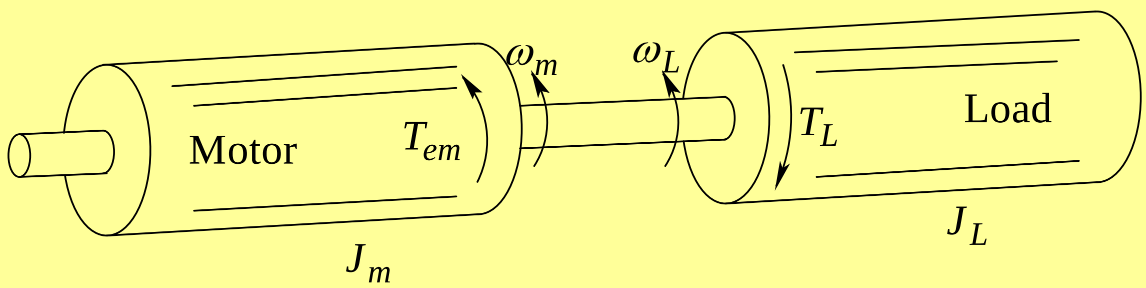
- Mechanical-Electrical Analog
- Electrical Modeling
- Coupling Mechanisms
- Four-Quadrant Operation
- Dynamic Operation

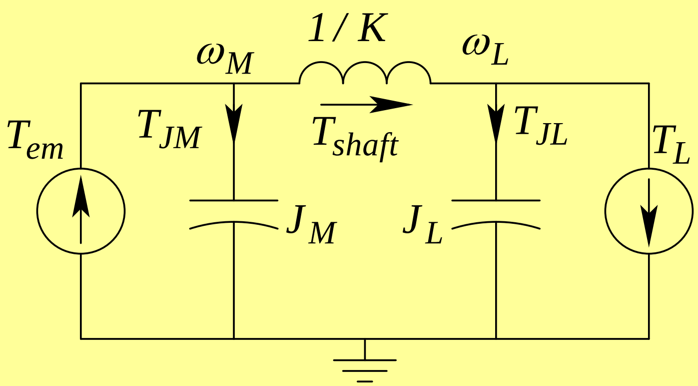
Mechanical - Electrical Analogy

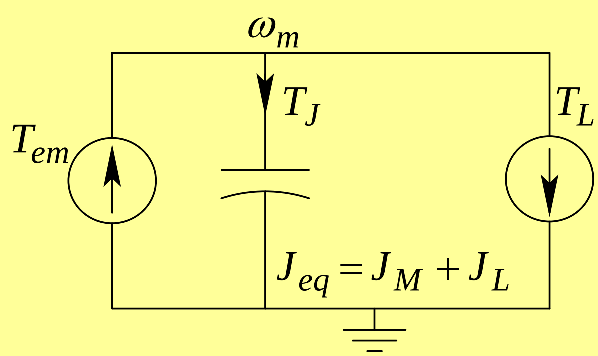
- Torque
- Angular Velocity
- Angular Displacement
- Moment of Inertia
- Spring Constant
- Damping Coefficient
- Coupling Ratio

- Current
- Voltage
- Flux Linkage
- Capacitance
- 1/Inductance
- 1/Resistance
- Transformer ratio

Electrical Analogy of Motor & Load







Finite shaft stiffness

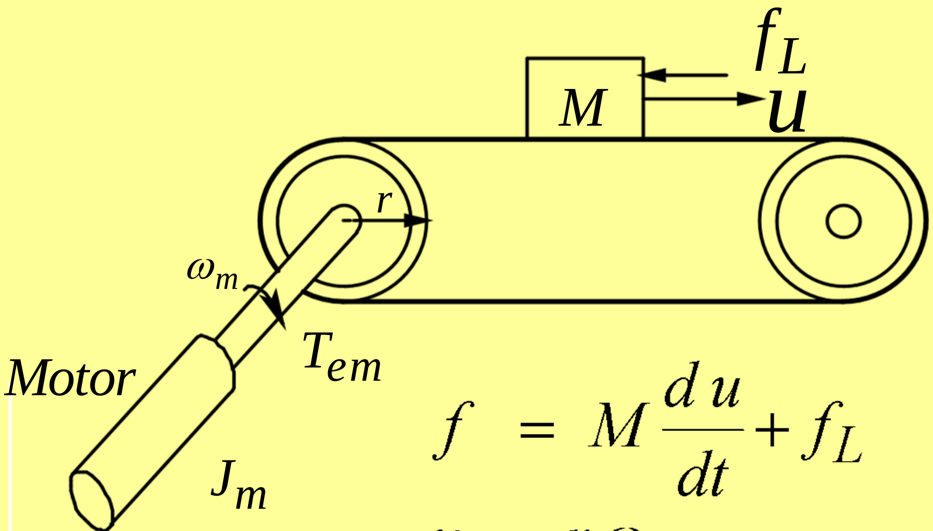
Infinite shaft stiffness

Coupling Mechanisms

- Required when
  - a (rotary) motor is driving a load which requires linear (translational) motion
  - motors prefer higher rotational speed than that required by the load
  - the axis of rotation needs to be changed

- Types
  - Conveyor belts (belt and pulley)
  - Rack and pinion or a lead-screw type of arrangement
  - Gear mechanisms

Conversion between Linear and Rotary Systems



J_m = motor inertia

M = mass of load

r = pulley radius

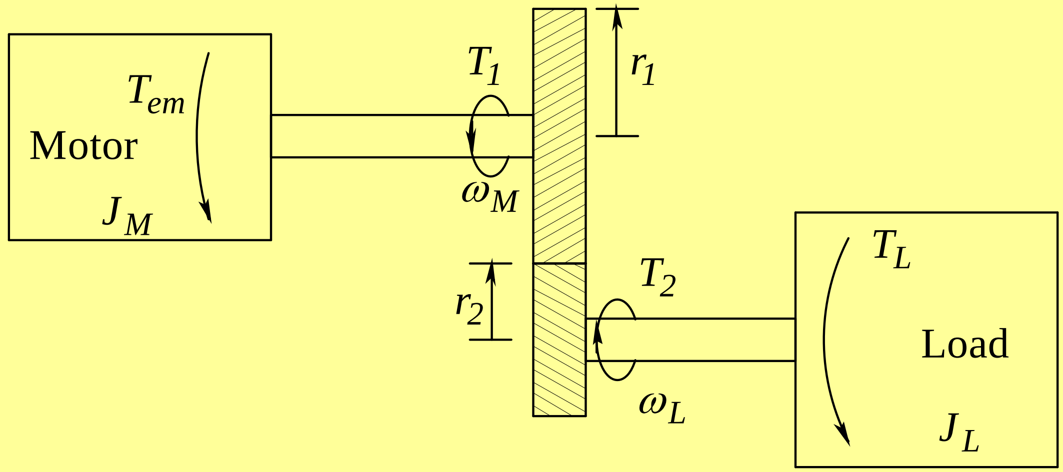
$$f = M\frac{du}{dt} + f_L$$

$$u = r\,\omega_m$$

$$T = r\,f = r^2 M\frac{d\omega_m}{dt} + r f_L$$

$$T_{em} = \underbrace{J_m\frac{d\,\omega_m}{dt}}_{\text{required to accelerate motor}} + \underbrace{r^2 M\frac{d\,\omega}{dt} + r\,f_L}_{\text{due to load}}$$

Gears



- Basic relationships: radius, speed, torque

Equal speeds at gear surfaces $\Rightarrow r_1 \omega_M = r_2 \omega_L$

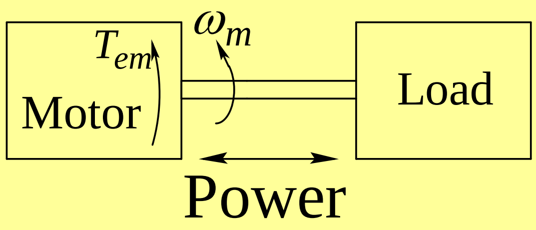
Power transferred across gears $\Rightarrow \omega_M T_1 = \omega_L T_2,$

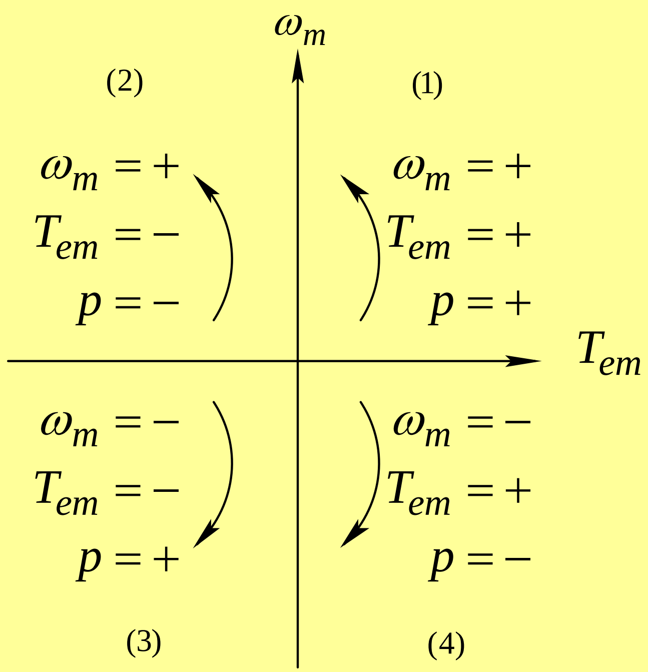
$$\Rightarrow \frac{r_1}{r_2} = \frac{\omega_L}{\omega_M} = \frac{T_1}{T_2} \qquad \& \underbrace{\left(T_{em} - J_M \frac{d\,\omega_M}{dt}\right)}_{T_1} \frac{\omega_M}{\omega_L} = \underbrace{\left(T_L + J_L \frac{d\,\omega_L}{dt}\right)}_{T_2}$$

- Geared up: speed increased, torque decreased $\omega_L > \omega_M;\ T_2 < T_1;\ r_2 < r_1$
- Geared down: speed decreased, torque increased

$\omega_L < \omega_M;\ T_2 > T_1;\ r_2 > r_1$

Four-Quadrant Operation





Dynamic Operation

- How the operating point changes with time
- Important for High Performance Drives
- Speed change: rapid and without any oscillations
- Requires good controller design

Summary

Mechanical System Modeling and Coupling Mechanisms

- Mechanical-Electrical Analog
- Electrical Modeling
- Coupling Mechanisms
- Four-Quadrant Operation
- Dynamic Operation