2/17/2022 ME 133

lecture 13

Last time:

- logic

$$Y = A \cdot (\overline{C} \cdot D) + (A + B) \cdot (C \cdot \overline{D})$$

C	D	$\overline{C} \cdot D$	$C \cdot \overline{D}$
0	0	0	0
1	0	0	1
0	1	1	0

$Y = (A \cdot D)$

$$Y = (A \cdot D) + (A+B) \cdot C$$

Goal: only use AND gates

Use De Morgan's law:

$$A + B + C \cdots = \overline{\bar{A} \cdot \bar{B} \cdot \bar{C} \cdots}$$

$$Y = \overline{\overline{(A \cdot D)} \cdot \overline{\overline{(\bar{A} \cdot \bar{B})} \cdot C}}$$

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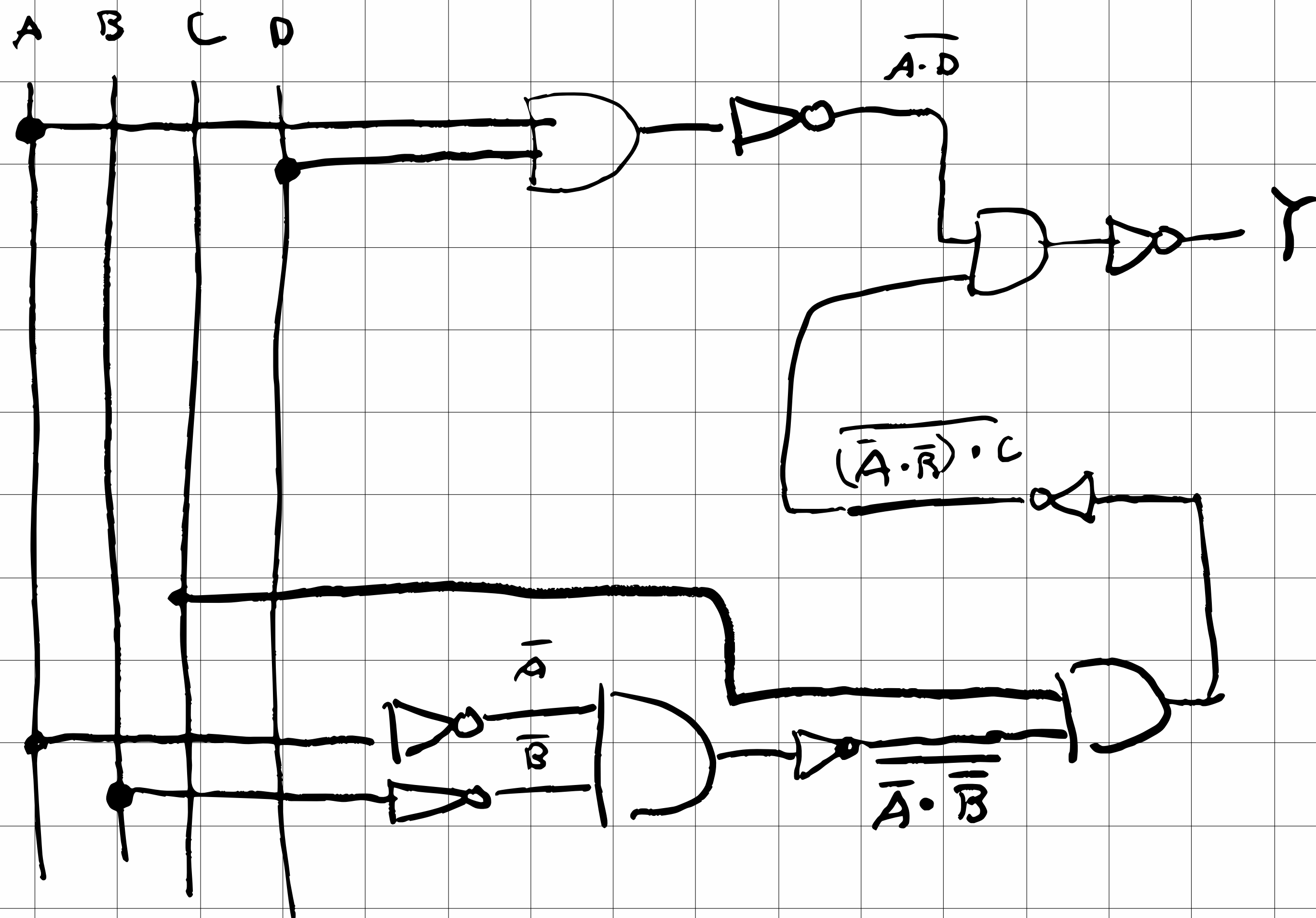
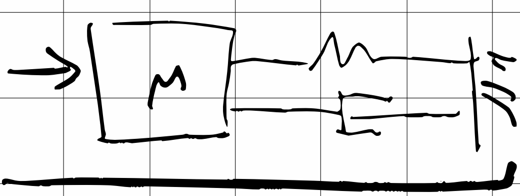
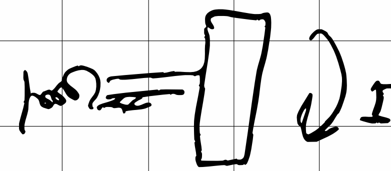


Actuators Ch. 10

Impedance controller



rotational eq. $\Rightarrow$

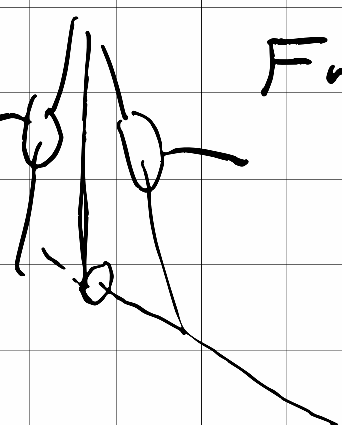


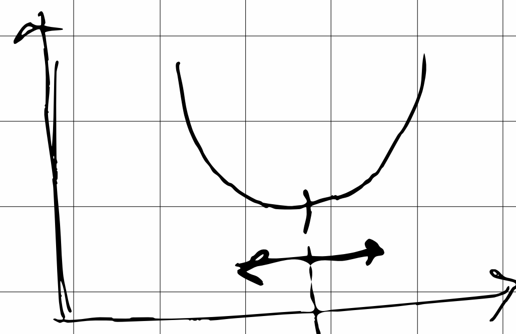
$$F_v = m_v\ddot{x} + B_v\dot{x} + K_v x$$

Motor : $M\ddot{x} + B\dot{x} = F_m + F_e$

$F_m = \ldots$

Actuator





Actuators?

Actuators provide physical interaction with the <u>word</u>.

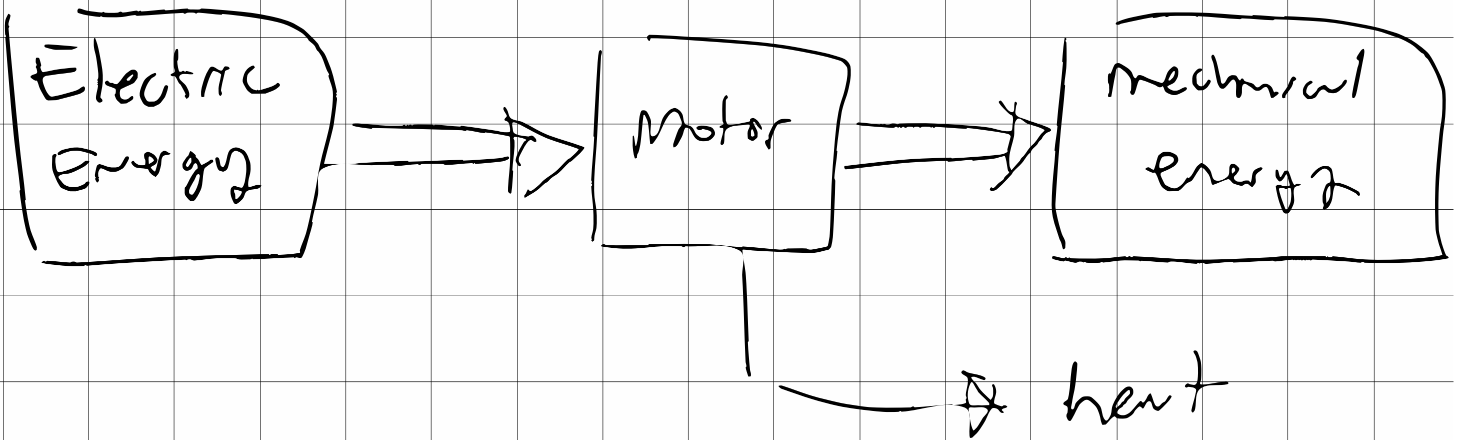
$$\boxed{\text{sensor}} \longrightarrow \boxed{\text{controller}} \longrightarrow \boxed{\text{Actuator}}$$

<u>Many types of Actuators</u>

- solenoid (on/off)
- Electric Motor
  - DC motor
  - AC motor
  - Stepper
  - Servomotor
- Hydraulics

- pneumatic
  - → soft fluidic Actuators
  - → pistons
- Piezo electric
- Combustion
  - IC engine
  - gun
  - Turbines
- smart materials
  - shape memory alloys
    - ↳ shape memory effect
  - Ionic polymer composite

Fundamental Principle



$$P_{in} = P_{out}$$

$$\underline{V \cdot I = \tau \cdot \omega} \quad \text{(ideal)}$$

torque (τ), angular velocity (ω)

$$\tau \cdot \omega = \eta \cdot I \cdot V$$

η efficiency.

Brushless DC $\longrightarrow$ 70 - 90%

AC Motors : AC current

Pros : simple design, high power, long life, fixed speed.

Cons : complex to control, poor speed performance poor position control

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DC motor :

pros : simple to control, inexpensive, variable speed

Cons : short life span, high maintenance low power.

Mechanical Principle

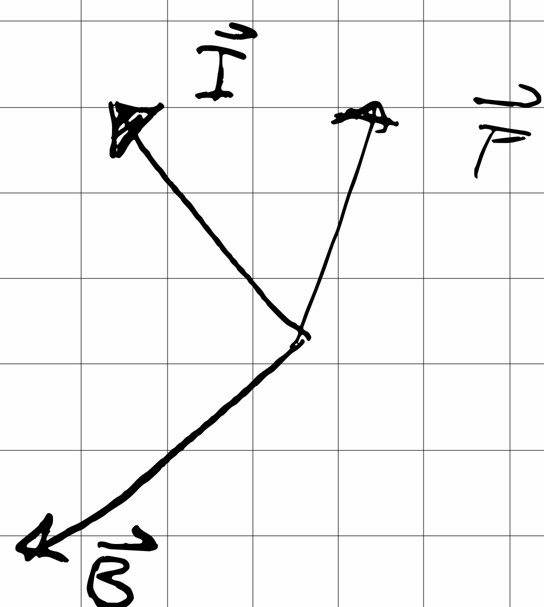
Lorentz Force: relates force on a conductor to the current in the conductor and the external magnetic field.

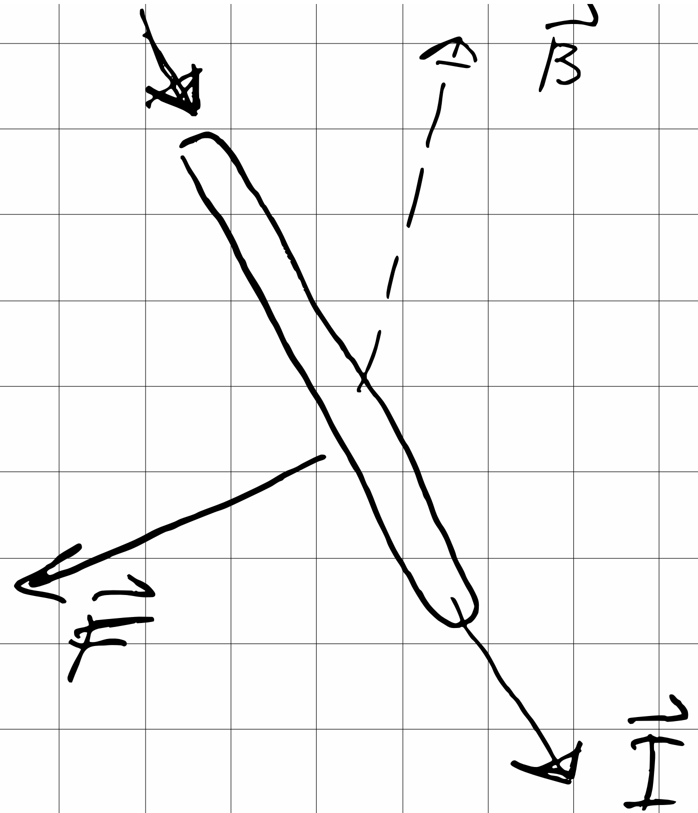
$$\vec{F} = \vec{I} \times \vec{B}$$

force vector

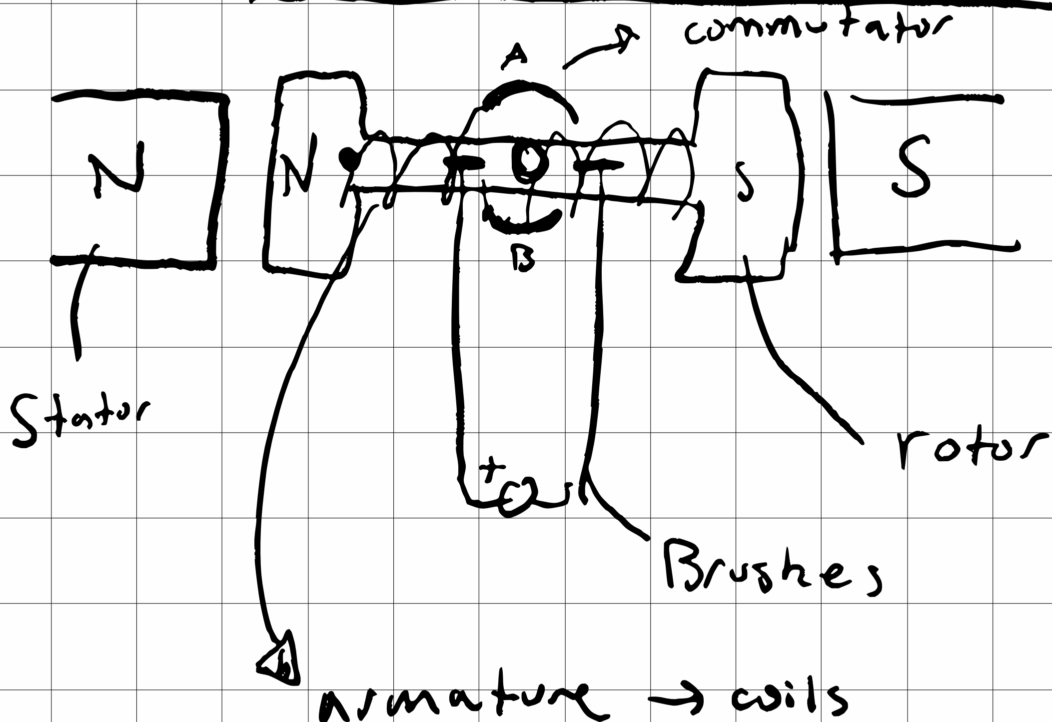
current vector

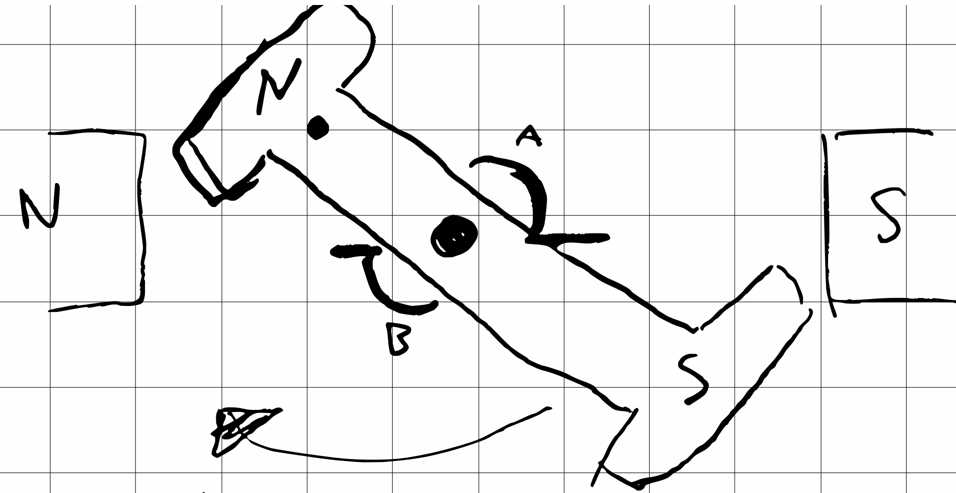
magnetic field vector



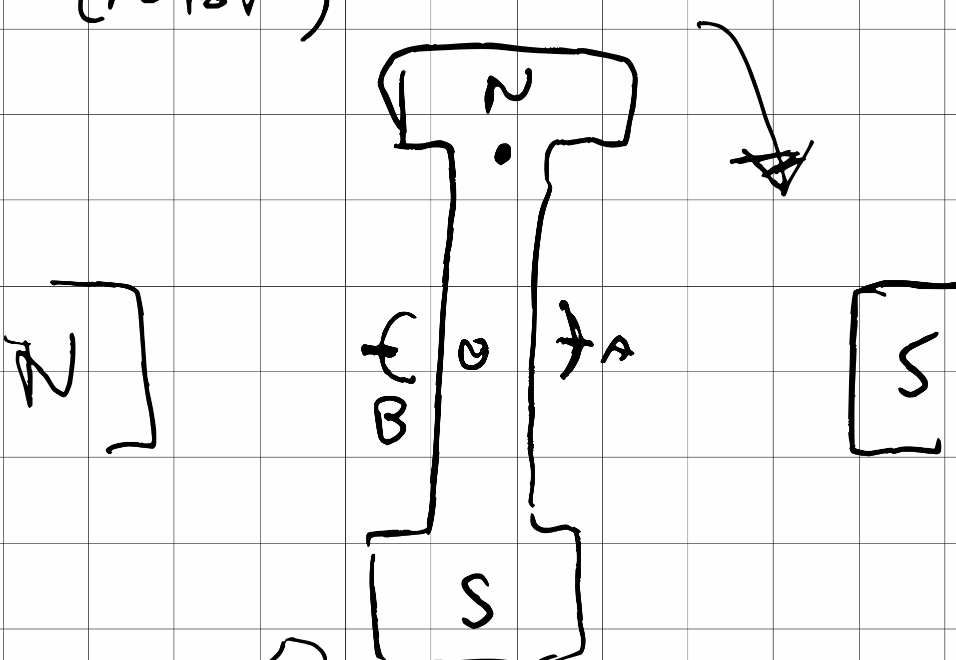


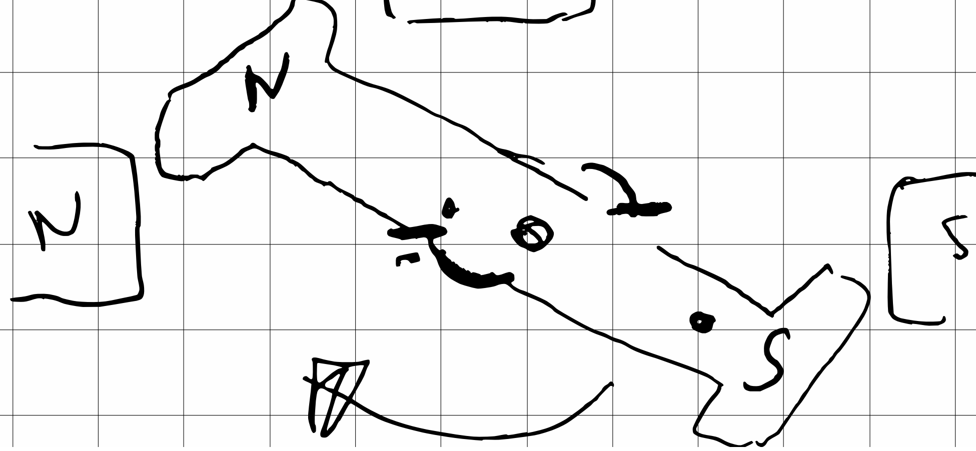
Two pole DC motor



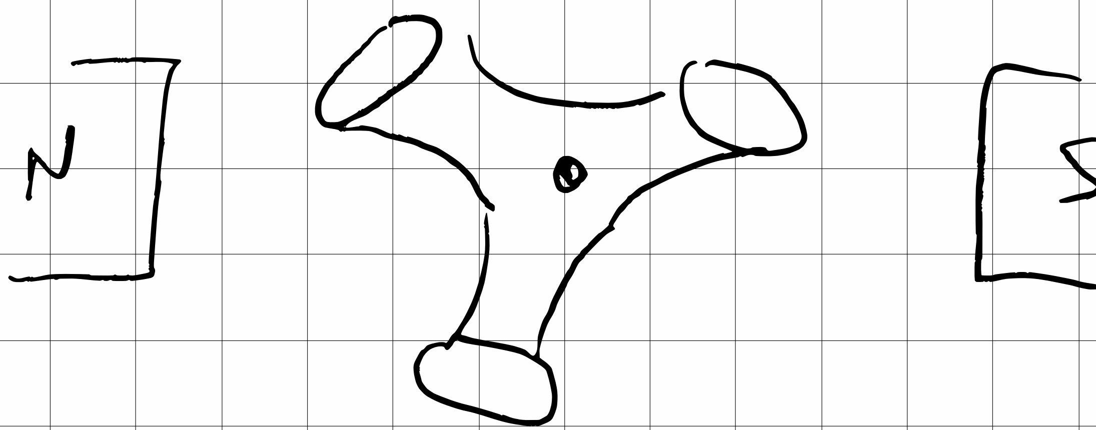


right brush contact commutator A
left brush contacts commutator B
creates current flow induces the magnetic field on the electr-magnetic (rotor)



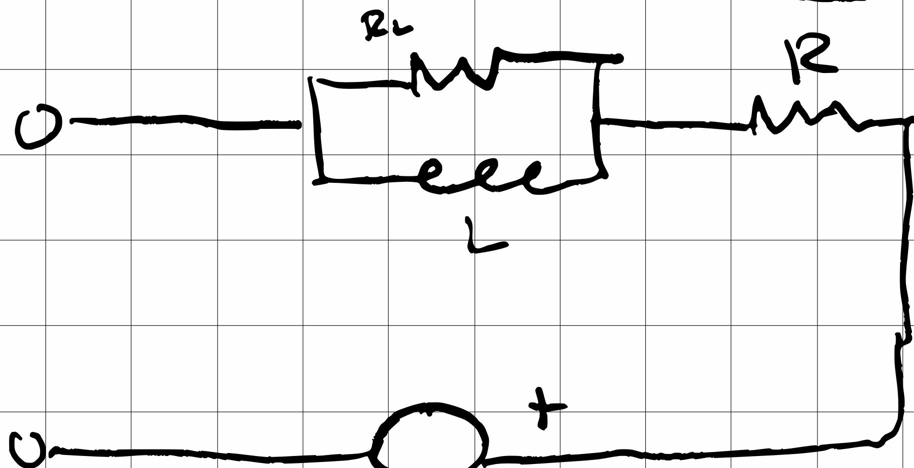


What is the #pole ~ velocity relationship
or
#poles ~ current ?



three poles

<u>DC motor Model</u>



Vemf : armature induced "back" voltage

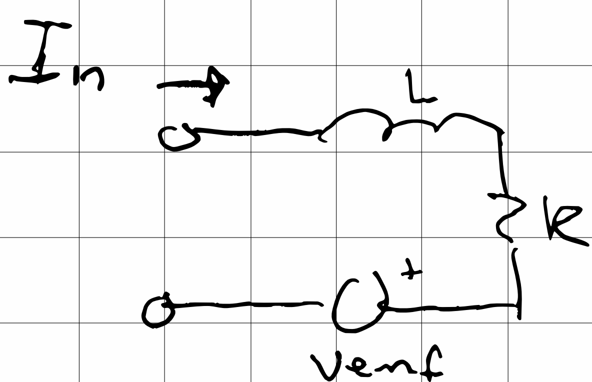
$V_{emf} : K_e \omega$

↑ electrical constant

R_L : model resistive loss in magnetic circuit $\underline{\underline{R_L >> R}}$

R : resistance in windings

with $R_L \approx 0$



$$\boxed{V_{in} = L \dot{I}_{in} + R I_{in} + k_e \omega}$$

Torque generation is directly proportional to current:

$$\tau = K_\tau I_{in}$$

$\uparrow$ torque constant

$$\rightarrow \tau = (J_a + J_2)\frac{d\omega}{dt} + \underbrace{\tau_f + \tau_L}_{\text{losses}}$$

friction

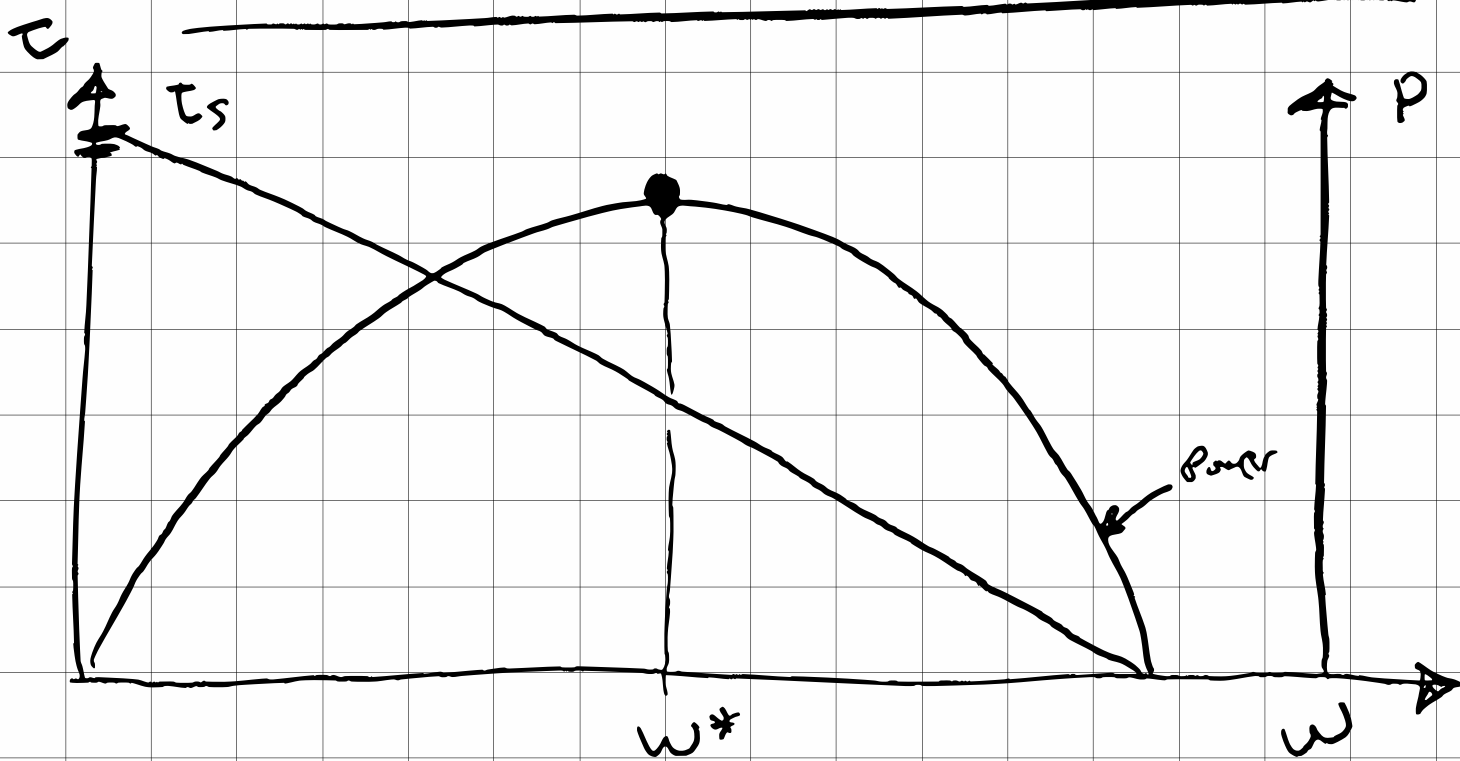
load dissipation

Steady state behavior

$$V_{in} = R I_{in} + K_e \omega$$

$$V_{in} = \left(\frac{R}{K_\tau}\right) \tau + K_e \omega$$

$$\therefore \tau = \left(\frac{K_\tau}{R}\right) V_{in} - \left(\frac{K_e K_\tau}{R}\right) \omega$$



Torque - speed curve
Power - speed curve

τ_s : starting torque
ω_s : no load speed

$$\tau(\omega) = \tau_s \left(1 - \omega/\omega_{max}\right)$$

$$P(\omega) = \tau \cdot \omega = \omega \tau_s \left(1 - \omega/\omega_{max}\right)$$

$$\frac{dP(\omega)}{d\omega} = 0$$

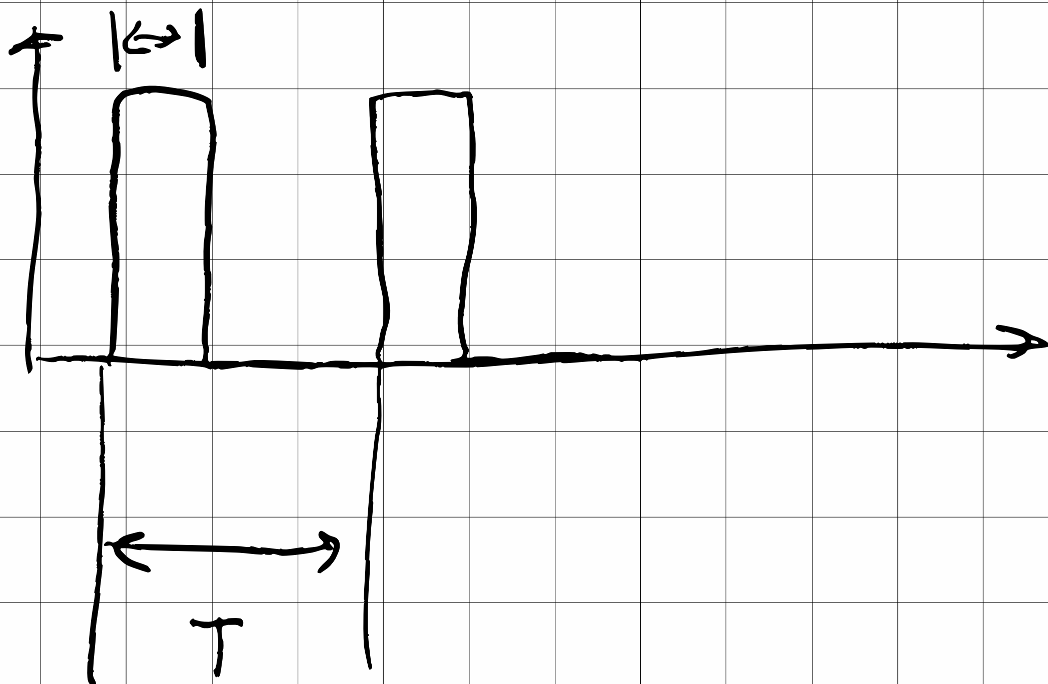
$$= \tau_s \left(1 - \frac{2\omega}{\omega_{max}}\right) = 0$$

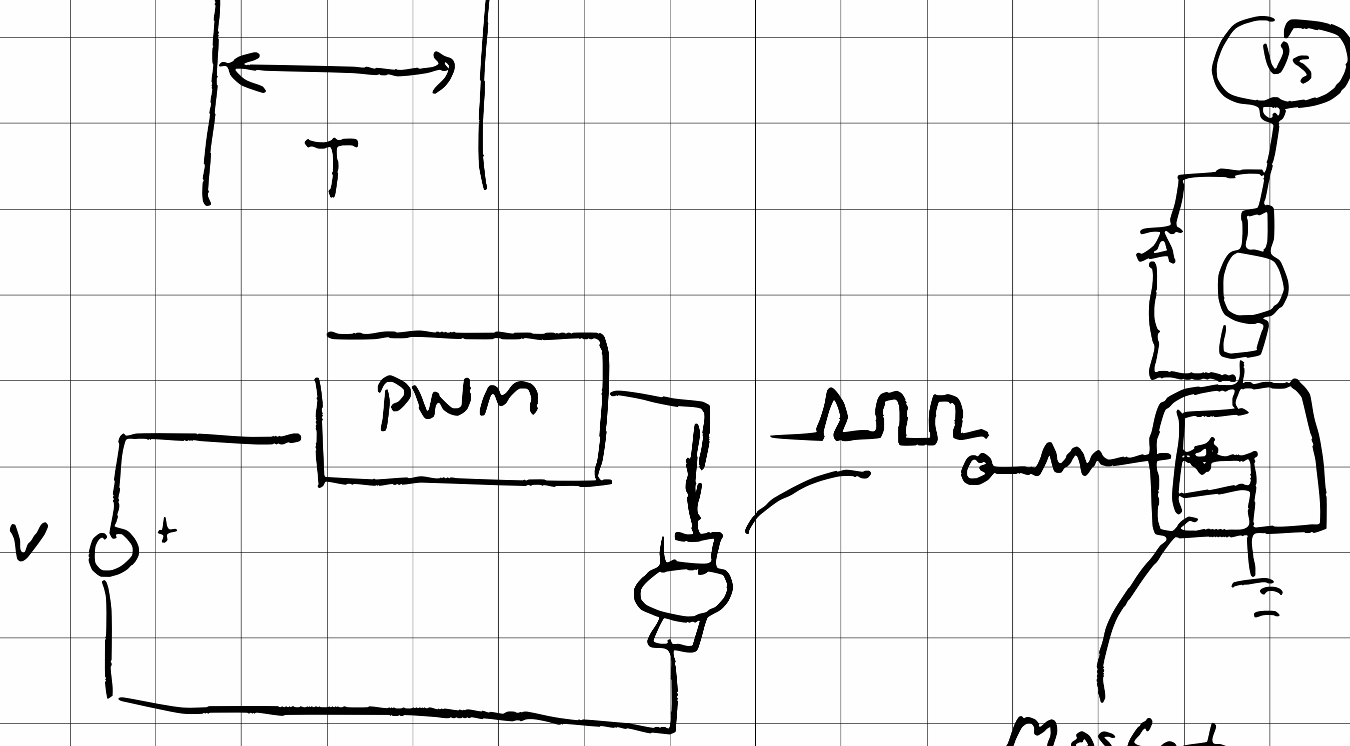
$$\boxed{\omega^* = \frac{1}{2}\omega_{max}}$$

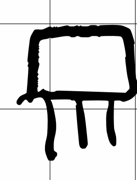
Best operating point for constant velocity application.

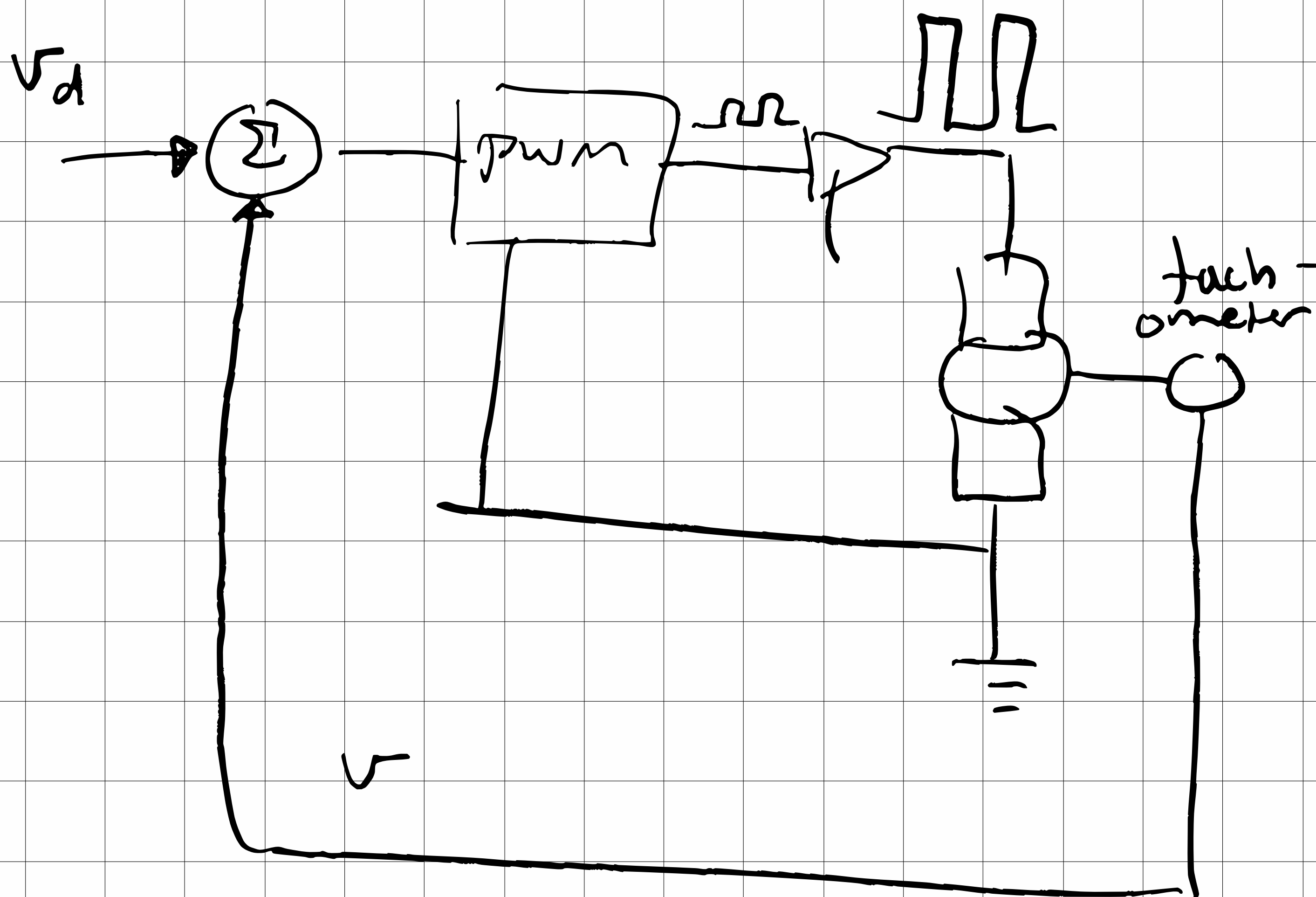
Control of DC motor

PWM : pulse width modulation









Speed control