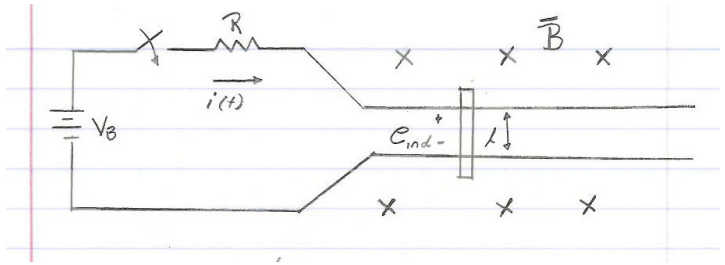
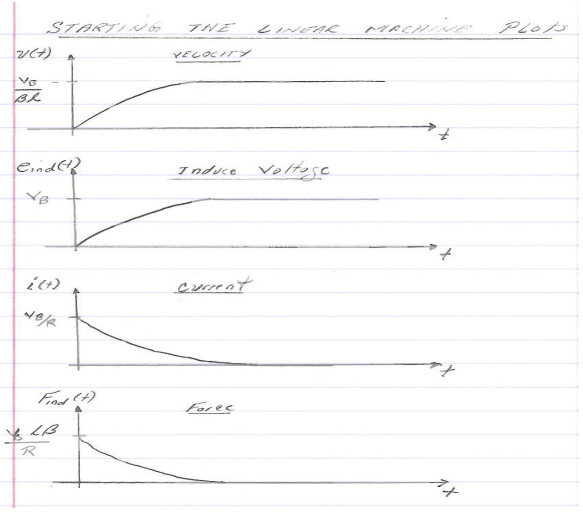
Linear DC Machine



4 Basic Eqn's

1. $\vec{F} = i(\vec{l} \times \vec{B})$
   Force, Current, Length (Direction of i), Mag. Flux Density
2. $e_{ind} = (\vec{v} \times \vec{B}) \cdot \vec{l}$
   Voltage, Velocity of Wire
3. $V_B = e_{ind} + iR$
4. $F_{NET} = ma$

Starting the Linear Machine Plots



Starting the Linear Machine

1. Close switch → current i flows

$$i = \frac{V_B - e_{ind}}{R} = \frac{V_B}{R}$$

$e_{ind} = 0$ since bar is at rest.

2. i causes F_{NET}

$F_{net} = i(l \times B)$ bar moves to right

3. As bar moves e_{ind} is produced

$e_{ind} = (\vec{v} \times \vec{B}) \cdot l$ positive upward

4. The net current is reduced

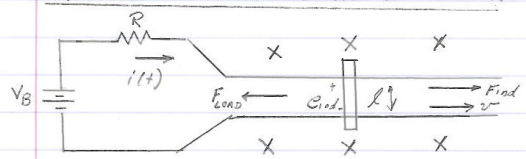
$$\downarrow i = \frac{V_B - e_{ind}\uparrow}{R}$$

5. F_{net} is reduced

$$F = i\,\ell\,B \quad \text{until} \quad F = 0$$

so bar will slow until, $e_{ind} = V_B$, $i = 0$, and moves at steady-state speed $v_{ss} = \frac{V_B}{B\ell}$

The Linear Machine as a Motor



What happens if an external load is applied after machine reaches steady-state?

1. $\overleftarrow{F_{net}} = \overleftarrow{F_{LOAD}} - \overrightarrow{F_{IND}}$ (bar will slow down)

2. $\downarrow e_{ind} = \downarrow v\,B\ell$ (e_{ind} decreases)

3. $\uparrow i = \frac{V_B - \downarrow e_{ind}}{R}$ (current increases)

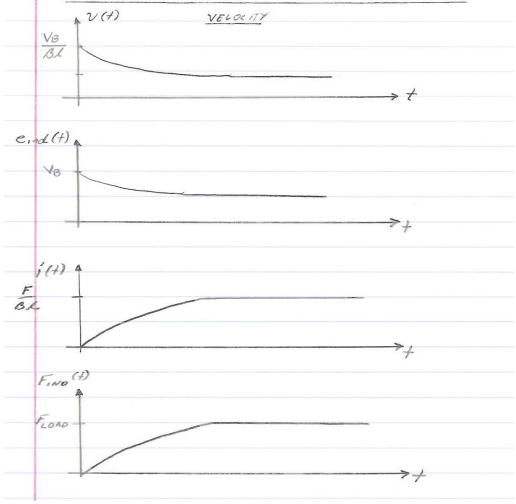
4. $\uparrow F_{ind} = \uparrow i\,\ell\,B$ (induced Force increases to be equal but opposite F_{LOAD})

5. $|F_{IND}| = |F_{LOAD}|$ at slower speed v

6. $P_{elec} = e_{ind}\,i \Rightarrow P_{mech} = F_{IND}\,v$

Since no losses are considered $P_{conv} = P_{elec} = P_{mech}$

Linear Machine as a Motor Plots



The Linear DC Machine as a Generator

What happens if we apply a force in the direction of motion of a machine at steady-state?

1. $\vec{F}_{net} = \vec{F}_{app} + \vec{F}_{ind}$ bar accelerates to right

2. $e_{ind} \uparrow = \vec{v} \beta \ell$ $e_{ind} \uparrow > V_B$

3. $i = \frac{V_B - e_{ind}}{R}$ $i < 0$ (reverses direction)

4. $\overleftarrow{F_{ind}} = (-i) \ell B$ induces force to left to oppose $F_{applied}$

5. $|F_{ind}| = |F_{applied}|$ at new higher speed.

Now the battery is being charged. Thus the machine is a generator. It converts $P_{mech} = F_{applied} v \Rightarrow P_{elec} = e_{ind} i$

Linear Machine Notes

1. Same machine acts as both a motor and a generator.

2. When $e_{ind} > V_B \Rightarrow$ generator

   when $V_B > e_{ind} \Rightarrow$ motor

3. When machine moved rapidly to right it was a generator.

   When machine moved slowly to right it was a motor.

The machine did NOT reverse direction of motion.

Linear Machine Example

Given: $V_B = 120^V$, $R = 0.3\Omega$, $B = 0.1\,T$, $\ell = 10m$

a) What is the max. starting current?

$$i = \frac{V_B - e_{ind}}{R} = \frac{120 - (0 \text{ at start-up})}{0.3} = 400^A$$

b) What is the steady-state velocity?

$e_{ind} = vB\ell = V_B$ at steady-state

$$v = \frac{V_B}{B\ell} = \frac{120}{(0.1)(10m)} = 120\,m/s$$

c) What is steady-state speed if a 30-N force pointing to the right is applied?

Steady-state occurs when $|\overleftarrow{F_{IND}}| = |\overrightarrow{F_{APP}}| = iLB$

So $i = \frac{30N}{(10m)(0.1)} = 30^A$ upward in bar

then $e_{ind} = V_B + iR = 120 + 30(0.3) = \underline{129^V}$

and $v = \frac{e_{ind}}{BL} = \frac{129}{(0.1)(10)} = \underline{129\ m/s}$

The machine is acting as a generator.

d) What is the elec. and mech power produced by the bar?

$P_{mech} = F \cdot v = 30N \cdot 129\ m/s = 3{,}870\ W$

$P_{elect} = e_{ind} \cdot i = 129^V \cdot 30^A = 3{,}870^W$

e) What is the steady-state speed if a 30N force in the left direction is applied to the bar.

$F_{app} = F_{IND} = iLB$ at steady-state

$i = \frac{F_{IND}}{BL} = 30^A$ (down through bar)

$e_{ind} = V_B - iR = 120 - 9 = 111^V$

$v_{ss} = \frac{e_{ind}}{BL} = \frac{111}{(0.1)(10)} = \underline{111\ m/s}$

The machine is acting as a motor.

f) If the bar is initially unloaded and the magnetic field changes to 0.08T, find v_{ss}.

initially $e_{ind} = V_B$ since bar is unloaded

finally $e_{ind} = V_B$ also since bar will still be unloaded.

$e_{ind} = V_B = v_{ss} BL$

$v_{ss} = \frac{120}{(0.08)(10m)} = \underline{150\ m/s}$

When the flux is reduced, the bar will speed-up. This also happens in dc motors.