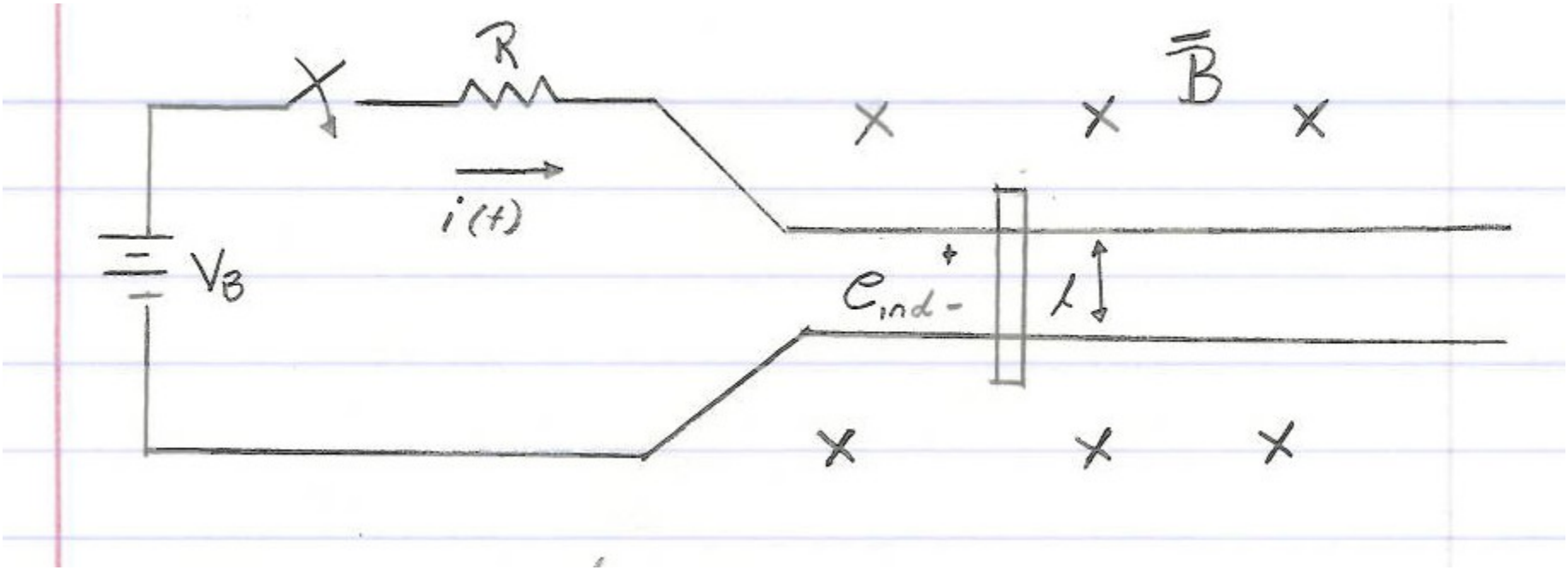
Linear DC Machine



4 Basic Eqn's

1. $$F = i(\vec{l} \times \vec{B})$$

FORCE — CURRENT — Length (Direction of i) — MAG. FLUX DENSITY

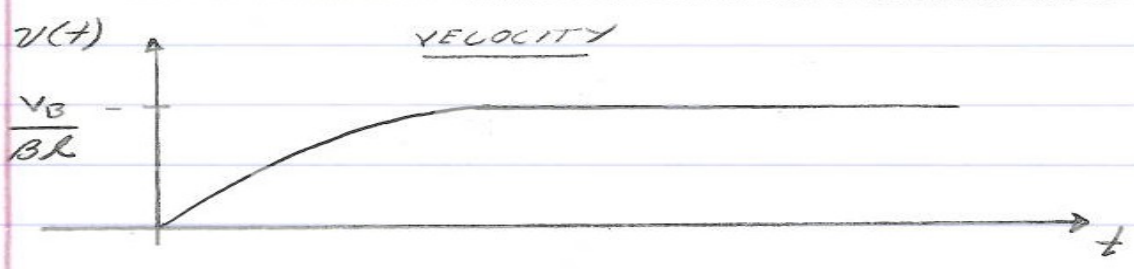
2. $$\mathcal{E}_{ind} = (\vec{v} \times \vec{B}) \cdot \vec{l}$$

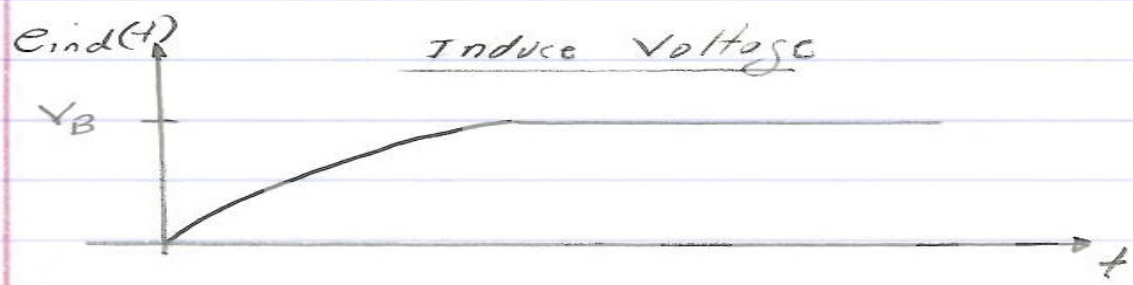
VOLTAGE — VELOCITY OF WIRE

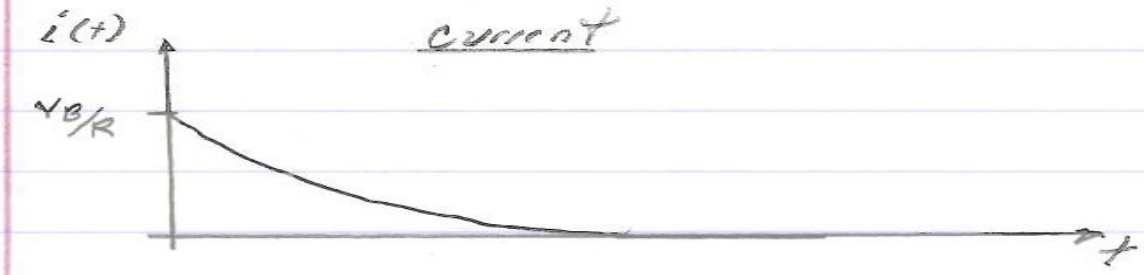
3. $$V_B = \mathcal{E}_{ind} + iR$$

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}

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

3. As bar moves e_{ind} is produced

$$e_{ind} = (\bar{v} \times \bar{B}) \cdot \ell$$ positive upward

4. The net current is reduced

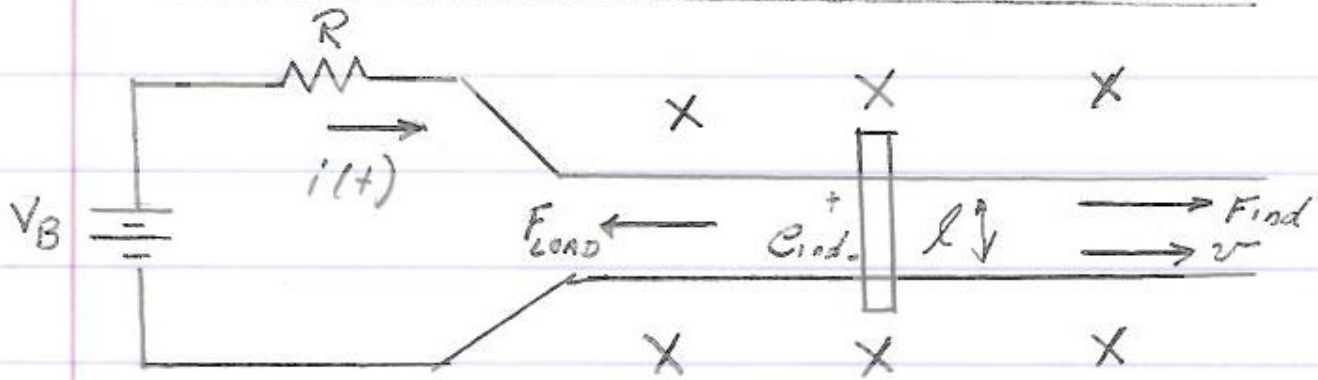
$$\downarrow i = \frac{V_B - e_{ind}\uparrow}{R}$$

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. $e_{ind} = v B l$ (e_{ind} decreases)

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

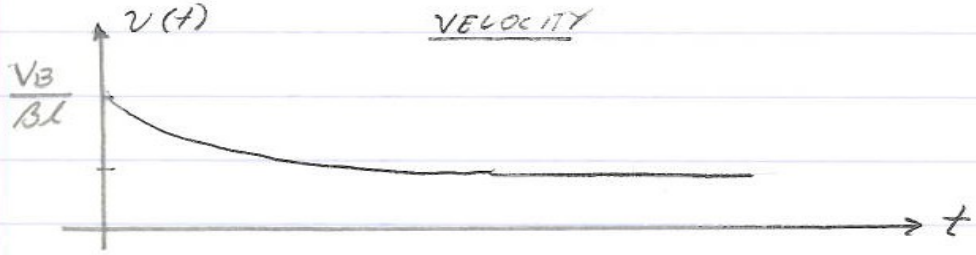
4. $F_{ind} = i l B$ (induced Force increases to be equal but opposite F_{LOAD})

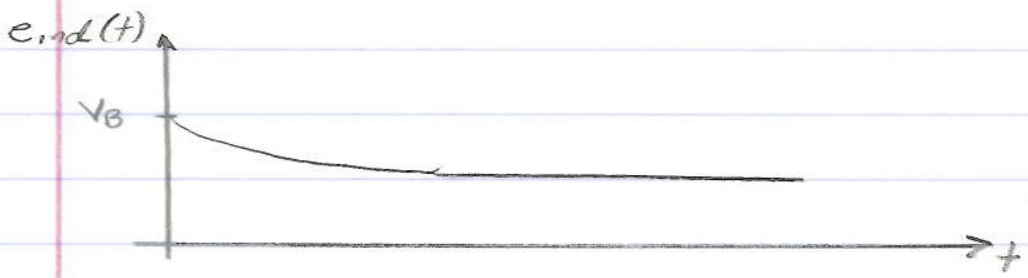
5. $|F_{IND}| = |F_{LOAD}|$ at slower speed v

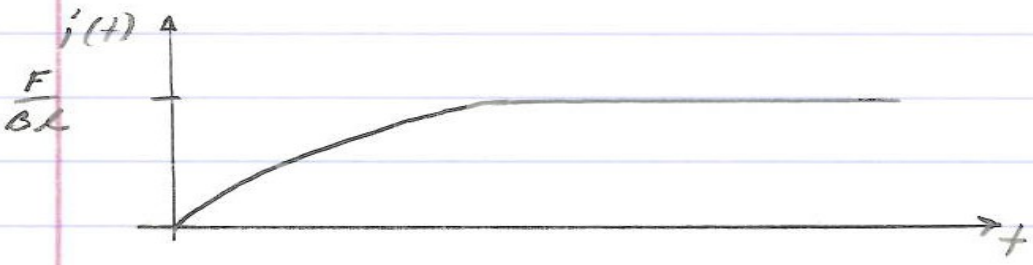
6. $P_{elec} = e_{ind} i \Rightarrow P_{mech} = F_{IND} v$

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

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

4. $\overleftarrow{F_{ind}} = (-i)\,\ell B$ induces force to <u>left</u> 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 <u>both</u> a motor and a generator.

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

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

3. When machine moved <u>rapidly to right</u> it was a <u>generator</u>.

   When machine moved <u>slowly to right</u> it was a <u>motor</u>.

The machine did <u>NOT</u> <u>reverse</u> direction of <u>motion</u>.

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?

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

b) What is the steady-state velocity?

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

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

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

Steady-state occurs when $|\vec{F}_{IND}| = |\vec{F}_{APP}| = iLB$

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?

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

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

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

$$F_{app} = F_{ind} = iLB \quad \text{at steady-state}$$

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

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

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

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.

$$e_{ind} = V_B = V_{ss} B \ell$$

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

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