HW #15 Solutions EE301

1) 15 VDC linear motor, steady state mode

$\hat{L} = 0.3m$, $R_{rail} = 0.01\Omega$

$\hat{B} = 0.5T$, bar velocity $v = 90 m/s$

Find F_{load} on bar and efficiency, η, of linear motor.

For steady state speed, we have the following equation derived in the DC Motor supplement:

$$v = \frac{V_{DC} - R_{rail}\frac{F_{load}}{BL}}{BL}$$

Solving for F_{load}, we get

$$vBL = V_{DC} - R_{rail}\frac{F_{load}}{BL}$$

$$vBL - V_{DC} = -R_{rail}\frac{F_{load}}{BL}$$

$$F_{load} = \frac{BL}{R_{rail}}(V_{DC} - vBL)$$

$$= \frac{(0.5T)(.3m)}{0.01\Omega}\left[15V - (90\tfrac{m}{s})(0.5T)(.3m)\right]$$

In resolving units in the second term, we know the unit relationship from Faraday's Law

$$E_{induced} = (\bar{v} \times \bar{B}) \cdot \bar{L}$$

$$\text{Volts} = \left(\tfrac{m}{s}\right)(T)m = T\frac{m^2}{s}$$

$$F_{load} = \frac{(0.5T)(.3m)}{0.01\Omega}\left[15V - (90\tfrac{m}{s})(0.5T)(.3m)\left(\frac{V}{T\frac{m^2}{s}}\right)\right]$$

$$= \frac{(0.5T)(.3m)}{0.01\Omega}\left[15V - 13.5V\right]$$

$$= 22.5\ \frac{TmV}{\Omega}\left[\frac{A}{V/\Omega}\ \frac{N}{TmA}\right]$$

↑ Ohm's Law unit conversion; ↑ unit conversion to N

$$\boxed{F_{load} = 22.5\,N}$$

1) Continued

$$\eta = \frac{P_{out}}{P_{in}}$$ ← from induced Voltage (P_out) ← from input voltage (P_in)

$P_{out} = E_{induced} I$

Using Faradays Law and relationship, $I = \frac{F_{load}}{BL}$, for steady state current,

$$P_{out} = \nu BL \frac{F_{load}}{BL} = \nu F_{load} = (90 \tfrac{m}{s})(22.5\,N)\left(\frac{W}{N \frac{m}{s}}\right)$$

$P_{out} = 2025\,W$

$$P_{in} = V_{DC} I = V_{DC} \frac{F_{load}}{BL} = (15V)\frac{22.5\,N}{(.5T)(.3m)}\left(\frac{TmA}{N}\right)\left(\frac{W}{VA}\right)$$

$P_{in} = 2250\,W$

$$\eta = \frac{2025\,W}{2250\,W} = 0.9 = \boxed{90\%}$$

2) 20VDC Linear Motor, steady state mode

$P_{out} = 5kW$, $\eta = 0.95$, $\hat{B} = 0.8T$

Find steady state current, I.

Let's use $P_{in} = V_{DC} I$ to find I, but we need to find P_{in} first.

$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_{in} = \frac{P_{out}}{\eta} = \frac{5kW}{0.95} = 5.26kW$$

Then,

$$I = \frac{P_{in}}{V_{DC}} = \frac{5.26kW}{20V}$$

$$\boxed{I = 263A}$$

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3) 30 VDC Linear Motor, steady state mode

$\hat{B} = 0.8T$, $L = 10m$ (moveable bar)

$R_{rail} = 0.02\Omega$, $F_{load} = 40N$

Find velocity of bar, v.

$$v = \frac{V_{DC} - R_{rail}\frac{F_{load}}{BL}}{BL}$$

$$= \frac{30V - (0.02\Omega)\left(\frac{40N}{(0.8T)(10m)}\right)}{(0.8T)(10m)}\left(\frac{T m A}{N}\right)\left(\frac{V}{A\Omega}\right)$$

$$= \frac{30V - 0.10V}{(0.8T)(10m)}\left(\frac{T\frac{m^2}{s}}{V}\right)$$

$$\boxed{v = 3.74\frac{m}{s}}$$