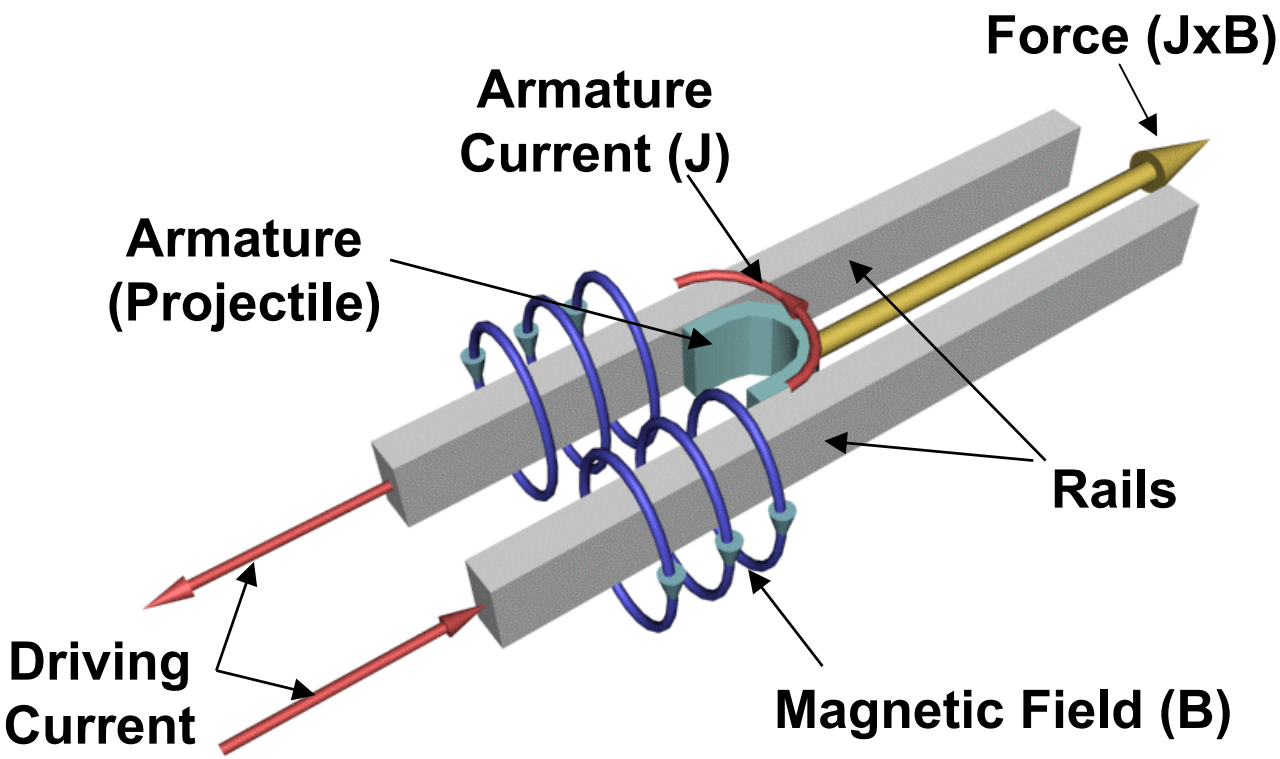
Electromagnetic Rail Gun

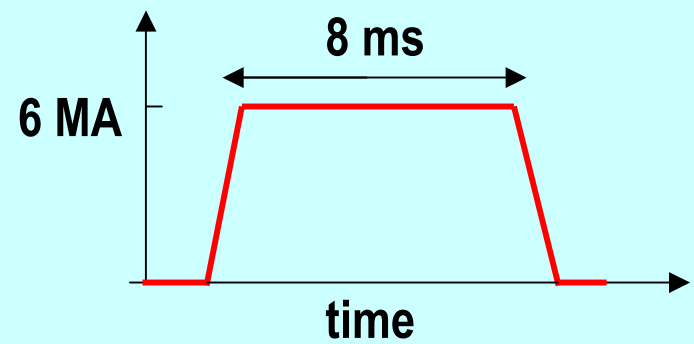


Current Flowing in the Rails Creates a Magnetic Field Which Interacts with the Current in the Armature to Generate a Lorentz (JxB) Force

Electrical Power Requirements

Notional Navy EM Gun Requirements:

- Flt. Mass – 15 kg
- Launch Mass – 20 kg
- Launch Velocity – 2.5 km/s
- Muzzle Energy – 63 MJ
- Breech Energy – ~150 MJ
- Barrel Length – 10 m
- Peak Accel. – 45 kgee
- Firing Rate – 6 to 12 RPM



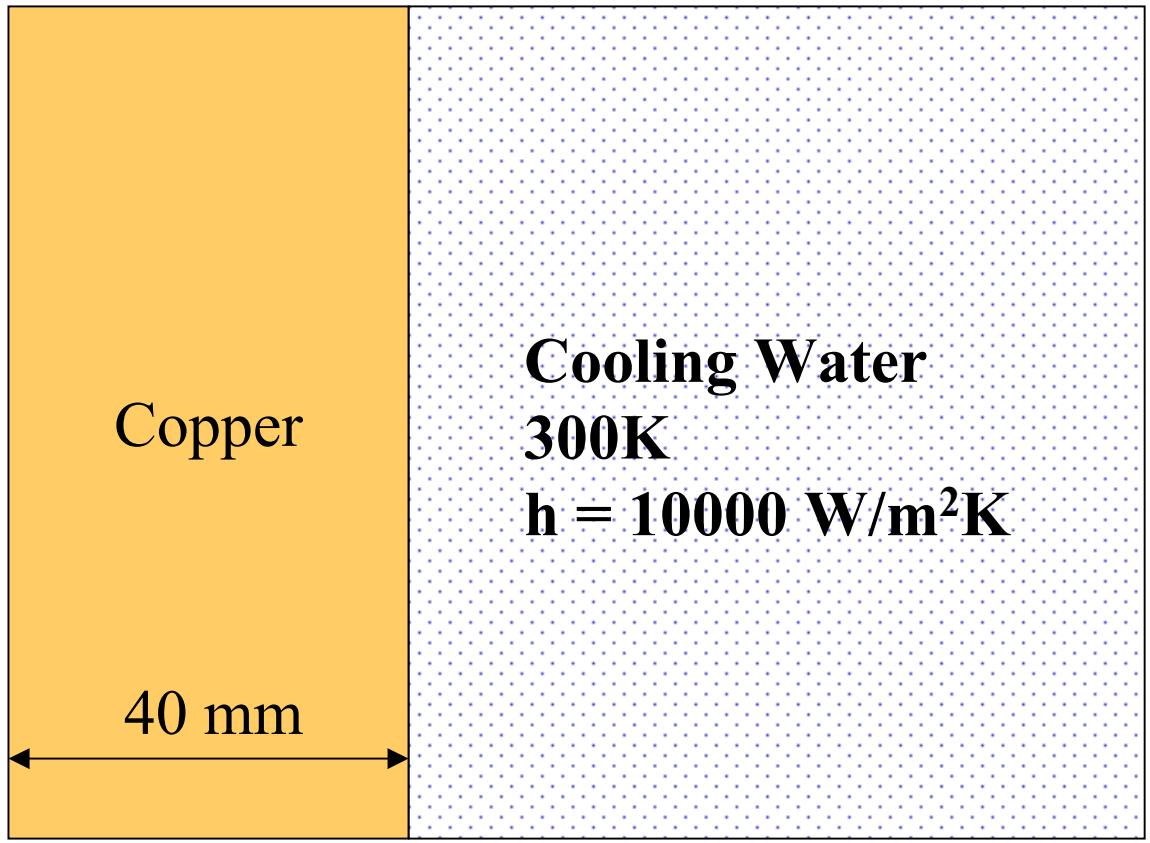
- Peak Input Voltage - ~12 kV
- Peak Charging Power - 15 to 30 MW

Steady State Problem

$Q = 31.5\ \text{MJ}$

every 10 seconds

Adiabatic



Inside Face of Rail

Rail Dimensions
10 m x 150 mm x 40 mm

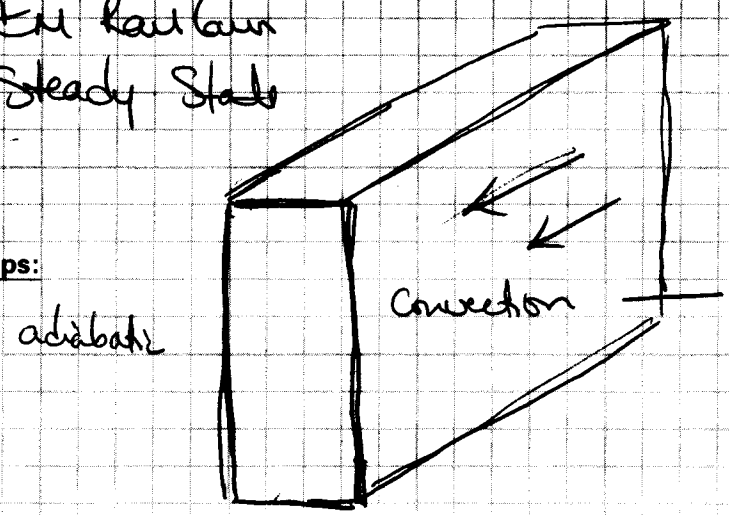
PROBLEM NO.	MECHANICAL ENGINEERING DEPARTMENT	NAME .....
DATE		SECTION .....

Given: EM Rail Gun
Steady State

$\dot{q} = 6.67 \frac{MW}{m^3}$

Find:

Relationships:



$T_\infty = 300\,K$

$h = 10{,}000\ W/m^2K$

System Sketch or FBD

Solution: Pure Copper – $K = 401\ W/m\,K$

$$\cancel{\rho C_p \frac{\partial T}{\partial t}} = K \frac{\partial^2 T}{\partial x^2} + \dot{q}$$

$$\frac{d^2T}{dx^2} = -\frac{\dot{q}}{K} = -16{,}626 \frac{W/m^3}{W/m\,K}$$

$$\frac{d^2T}{dx^2} = -16{,}626 \frac{K}{m^2}$$

$$\bar{q} = 16.626 \frac{K}{m^2}$$

$$\frac{dT}{dx} = -\bar{q}x + C_1$$

$$T(x) = -\bar{q}\frac{x^2}{2} + C_1 x + C_2$$

PROBLEM NO.	MECHANICAL ENGINEERING DEPARTMENT	NAME .....
DATE		SECTION .....

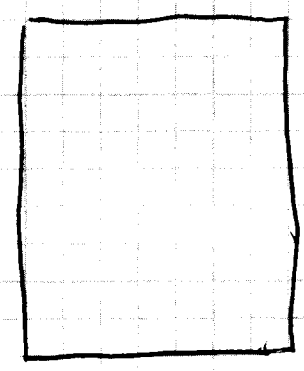
Given:

Find:

Relationships:

$$\left.\frac{dT}{dx}\right|_{x=0} = 0$$

Insulated



$$-k\left.\frac{dT}{dx}\right|_{x=L} = h\left[T - T_\infty\right]$$

System Sketch or FBD

Solution:

$$\left.\frac{dT}{dx}\right|_{x=0} = 0$$

$$\left.\frac{dT}{dx}\right|_{x=L} = -\frac{h}{k}\left[T - T_\infty\right]$$

apply 1st BC

$$\left.\frac{dT}{dx}\right|_{x=0} = C_1 = 0$$

$$T(x) = -\bar{q}\frac{x^2}{2} + C_2$$

apply 2nd BC

$$\left.\frac{dT}{dx}\right|_{x=L} = -\frac{h}{k}\left[-\frac{\bar{q}L^2}{2} + C_2 - T_\infty\right] = \bar{q}L$$

PROBLEM NO.	MECHANICAL ENGINEERING DEPARTMENT	NAME .....
DATE		SECTION .....

Given:

$$-\frac{qL^2}{2} + C_2 - T_\infty = +\bar{q}L\cdot\frac{k}{h}$$

Find:

Relationships:

$$C_2 = T_\infty + \bar{q}\frac{L^2}{2} + \bar{q}L\cdot\frac{k}{h}$$

System Sketch or FBD

Solution:

$$T(x) = -\bar{q}\frac{x^2}{2} + \bar{q}\frac{L^2}{2} + T_\infty + \bar{q}L\cdot\frac{k}{h}$$

$$\boxed{T(x) = \frac{\bar{q}}{2}\left[L^2 - x^2\right] + \bar{q}\frac{L\cdot k}{h} + T_\infty}$$

$H := .15$ $\quad W := 10$

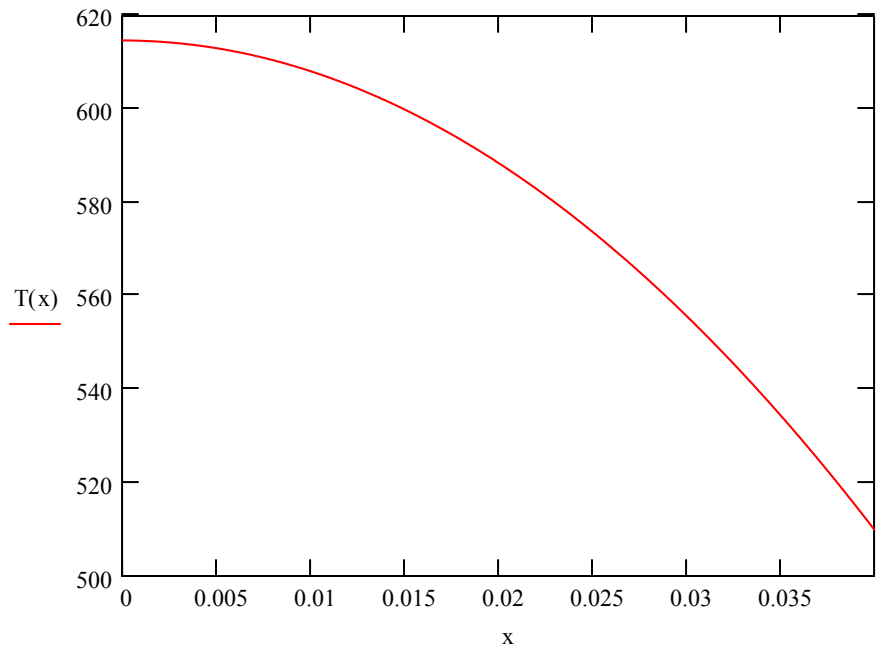
$L := 0.04$ $\quad Tinf := 300$ $\quad Qrail := 31.5 \cdot 10^{6}$

$k := 401$ $\quad t := 10$

$h := 10000$ $\quad qdot := \dfrac{Qrail}{L \cdot H \cdot W \cdot t}$

$qdot = 5.25 \times 10^{7}$

$$T(x) := \frac{qdot}{2 \cdot k} \cdot \left(L^{2} - x^{2}\right) + Tinf + L \cdot \frac{qdot}{h}$$



$T(0) = 614.738$