

Análisis por elementos finitos de los generadores termoeléctricos y sus aplicaciones aeroespaciales



UNIVERSIDAD
POLITECNICA
DE VALENCIA

Ángel González de la Vara

Director: José L. Pérez Aparicio
Codirector: Pablo Moreno Navarro

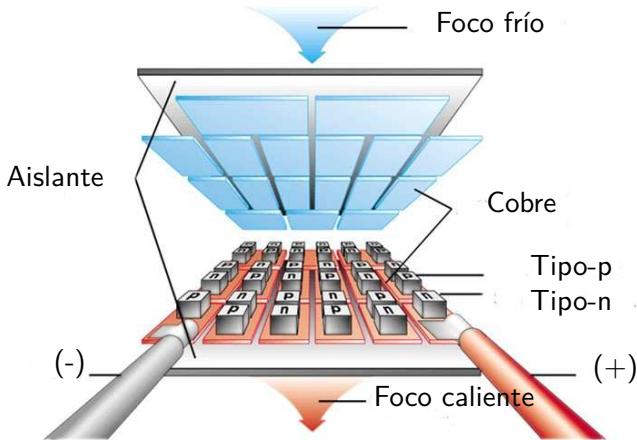
Universitat Politècnica de València, ETSID

Septiembre de 2017

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Dispositivos termoelectricos

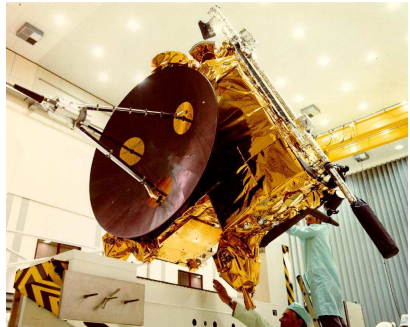


Aplicaciones aeroespaciales

» Generadores termoelectricos de radioisotopos (RTG)



(a) Mars Rover Curiosity



(b) Sonda Ulysses

Ecuaciones de Maxwell

$$\left. \begin{aligned} \nabla \times \mathbf{E} &= -\frac{\partial \mathbf{B}}{\partial t} \\ \nabla \times \mathbf{H} &= \mathbf{j} + \frac{\partial \mathbf{D}}{\partial t} \\ \nabla \cdot \mathbf{D} &= \rho_q \\ \nabla \cdot \mathbf{B} &= 0 \end{aligned} \right\}$$

Ecuaciones de Maxwell

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- » \mathbf{E} : Campo eléctrico
- » \mathbf{D} : Desplazamiento eléctrico
- » \mathbf{H} : Campo magnético
- » \mathbf{B} : Flujo magnético
- » \mathbf{j} : Flujo eléctrico

Ecuaciones de transporte

$$\left. \begin{aligned}
 \mathbf{j} &= \underbrace{\gamma \mathbf{E}}_{\text{Ohm}} - \underbrace{\gamma \boldsymbol{\alpha} \nabla T}_{\text{Seebeck}} \\
 \mathbf{q} &= \underbrace{\Pi \mathbf{j}}_{\text{Peltier}} - \underbrace{\kappa \nabla T}_{\text{Fourier}}
 \end{aligned} \right\} \quad \boldsymbol{\alpha} = \begin{bmatrix} \alpha & -NB_z & NB_y \\ NB_z & \alpha & -NB_x \\ -NB_y & NB_x & \alpha \end{bmatrix}$$

Ecuaciones de transporte

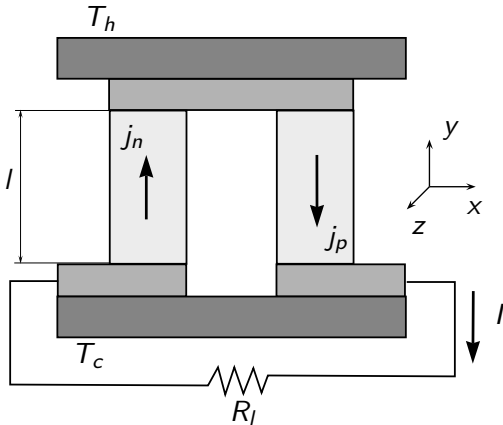
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$$\boldsymbol{\alpha} = \begin{bmatrix} \alpha & -NB_z & NB_y \\ NB_z & \alpha & -NB_x \\ -NB_y & NB_x & \alpha \end{bmatrix}$$

$$u = \frac{j}{\kappa \nabla T} ;$$

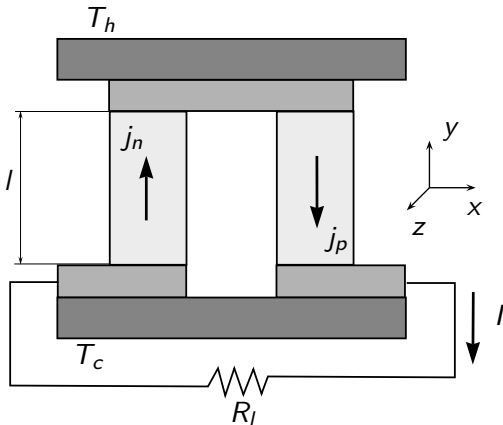
$$\Phi = \alpha T + \frac{1}{u}$$

Eficiencia termoeléctrica



$$\eta = \frac{W}{Q}$$

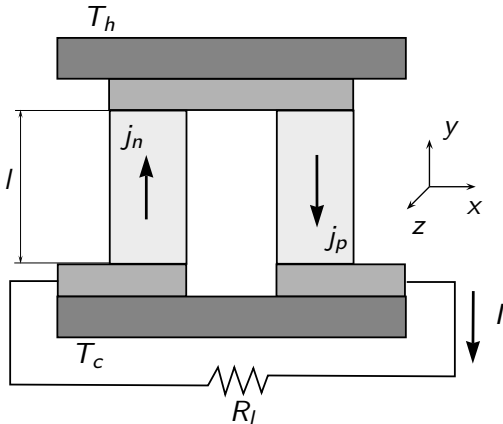
Eficiencia termoeléctrica



$$\eta = \frac{W}{Q}$$

$$\eta_{TE} = 1 - \frac{\alpha_c T_c + \frac{1}{u_c}}{\alpha_h T_h + \frac{1}{u_h}}$$

Eficiencia termoeléctrica

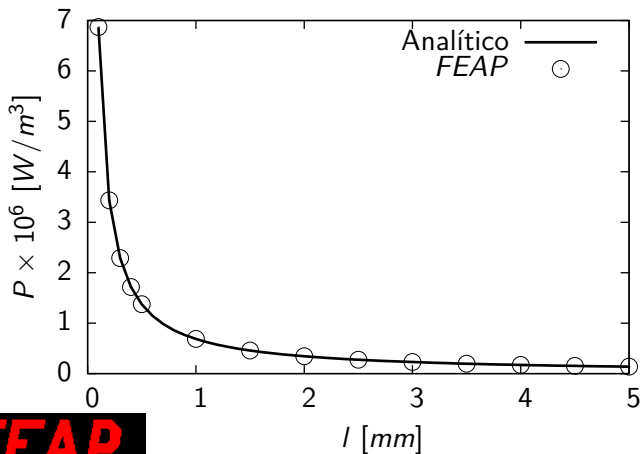


$$\eta = \frac{W}{Q}$$

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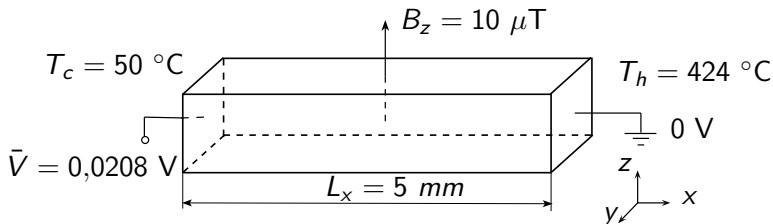
$$P = j \nabla \Phi$$

Comparación analítico-MEF

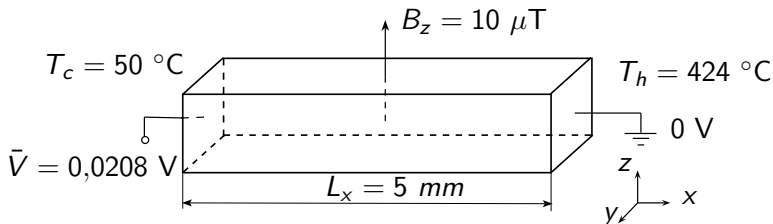


FEAP

Validación termogalvanomagnética

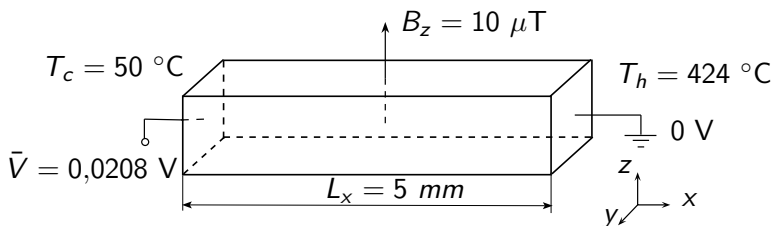


Validación termogalvanomagnética



$$\kappa \frac{\partial^2 T(x)}{\partial x^2} + \frac{j_x^2 + j_y^2}{\gamma} = 0$$

Validación termogalvanomagnética

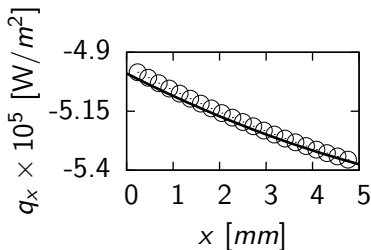
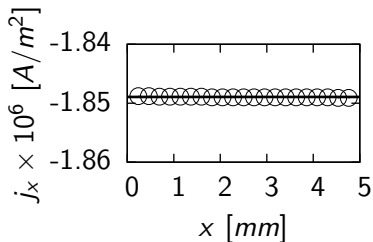
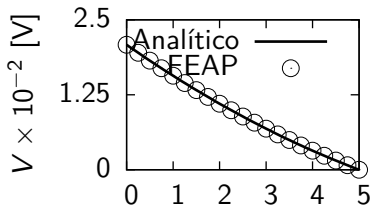
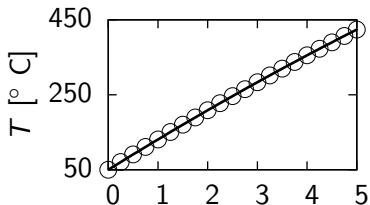


$$\kappa \frac{\partial^2 T(x)}{\partial x^2} + \frac{j_x^2 + j_y^2}{\gamma} = 0$$

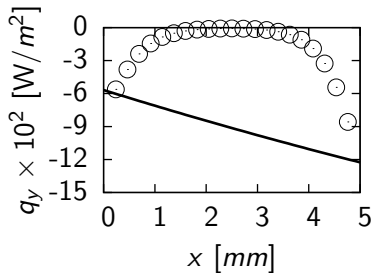
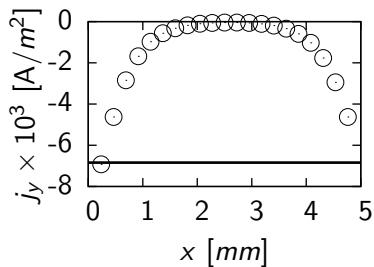
$$T(x) = T_c + f \frac{x^2}{2} + \frac{x}{L_x} \left[T_h - T_c - f \frac{L_x^2}{2} \right]$$

$$V(x) = \bar{V} - K f \frac{x^2}{2} - \frac{x}{L_x} \left[\bar{V} - K f \frac{L_x^2}{2} \right]$$

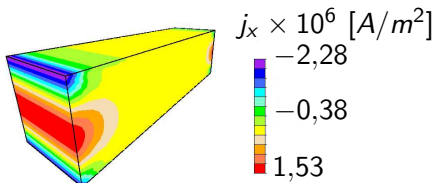
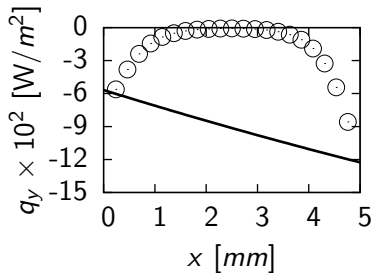
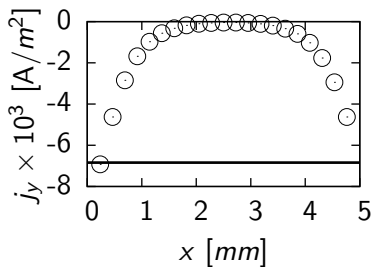
Resultados I



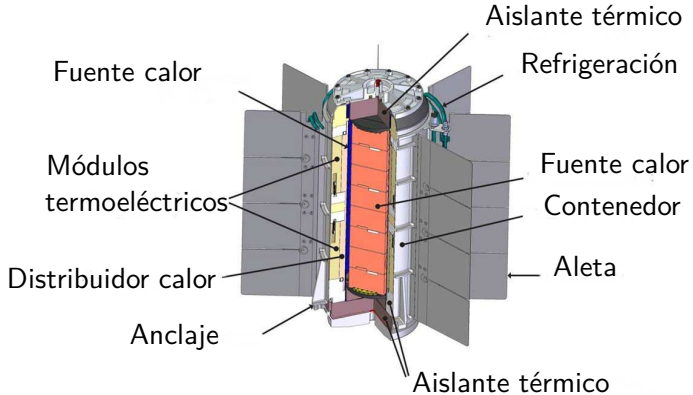
Resultados II



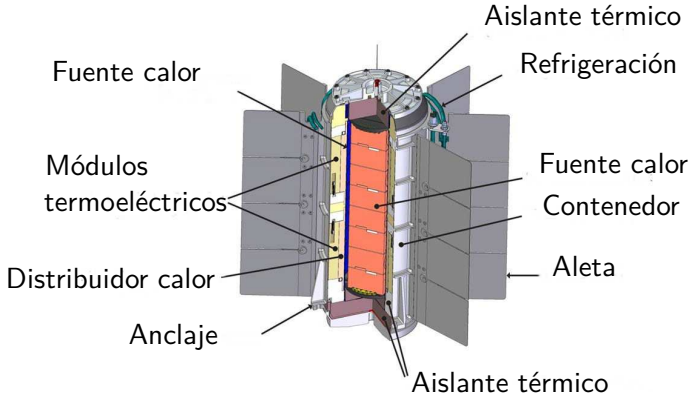
Resultados II



Configuración eMMRTG

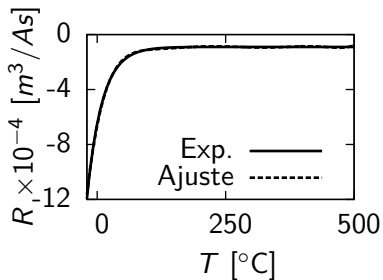
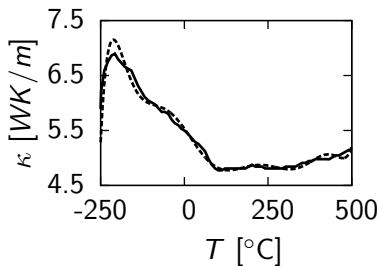


Configuración eMMRTG



$$\eta = 0,073 ; \quad W = 146 \text{ W}$$

Ajuste propiedades Skutterudite

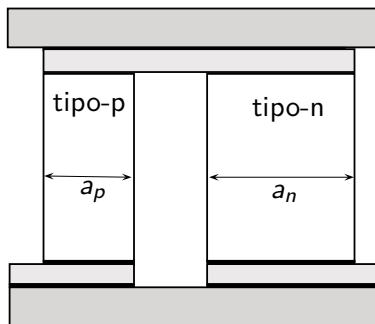


Análisis realizados

- » Estudio de longitud
- » Estudio de área
- » Estudio de flujo magnético
- » Generador segmentado
- » Generador cascada

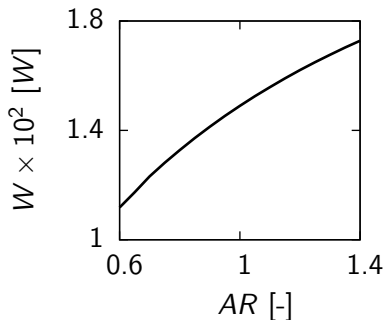
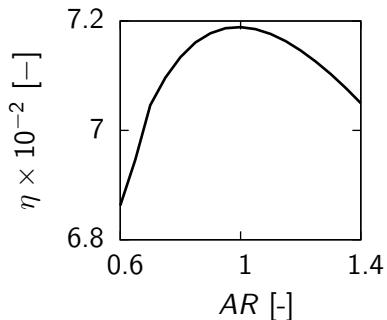
Estudio de área

Geometría

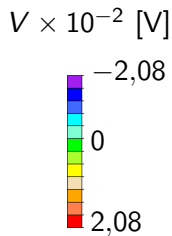
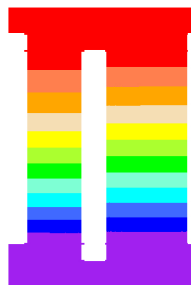


$$AR = \frac{a_n}{a_p}$$

Resultados I

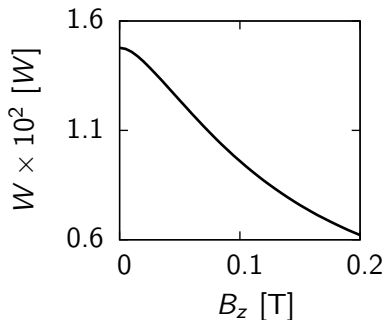
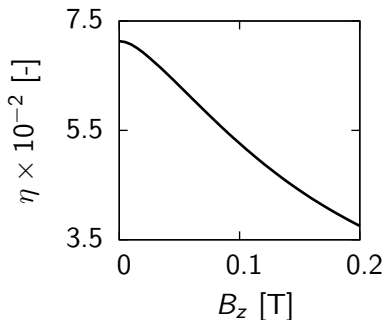


Resultados II

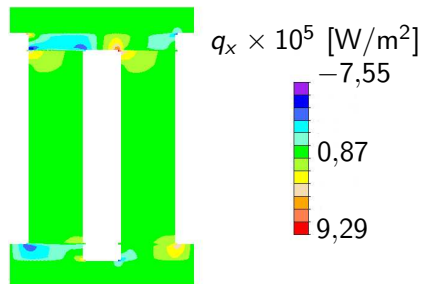
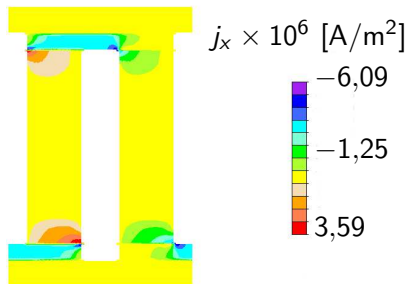


Estudio flujo magnético

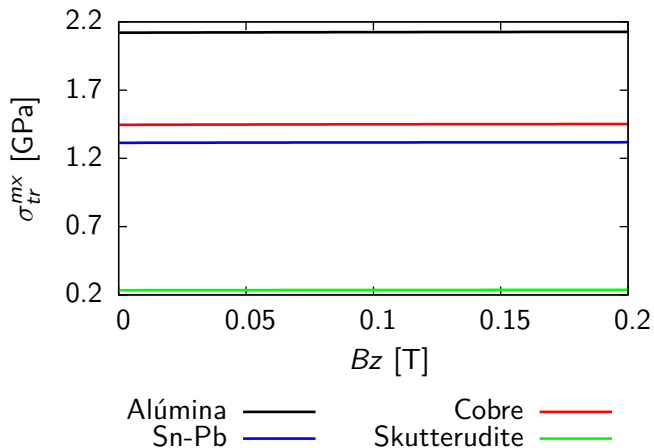
Resultados I



Resultados II

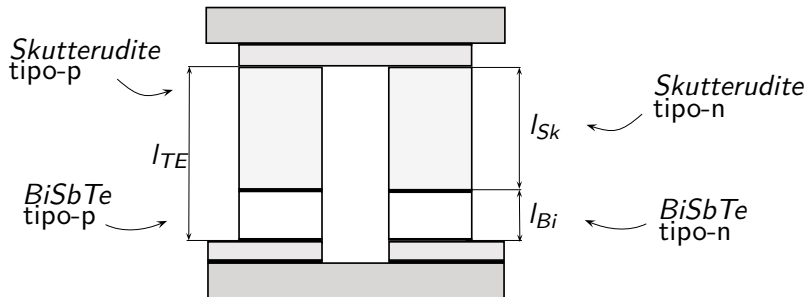


Resultados III

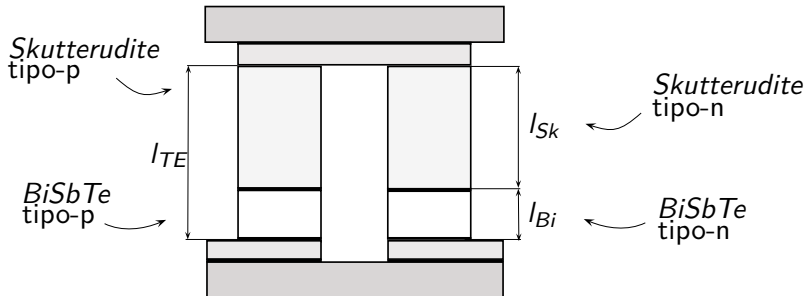


Generador segmentado

Geometría

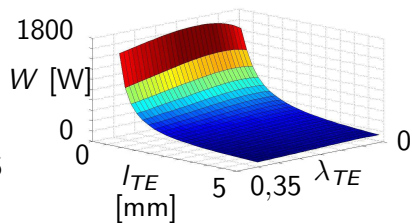
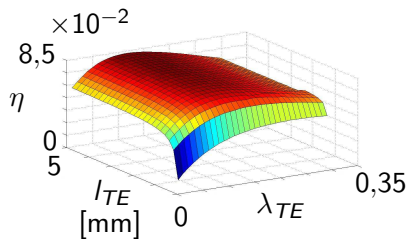


Geometría

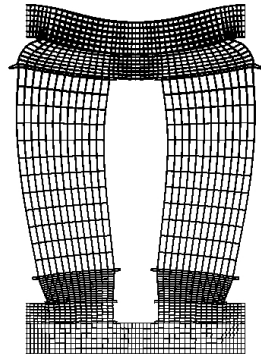
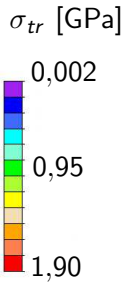
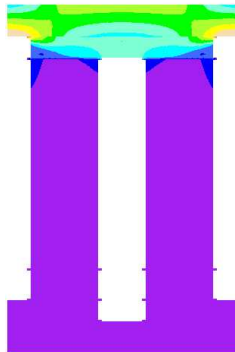


$$\lambda_{TE} = \frac{l_{Bi}}{l_{TE}}$$

Resultados I

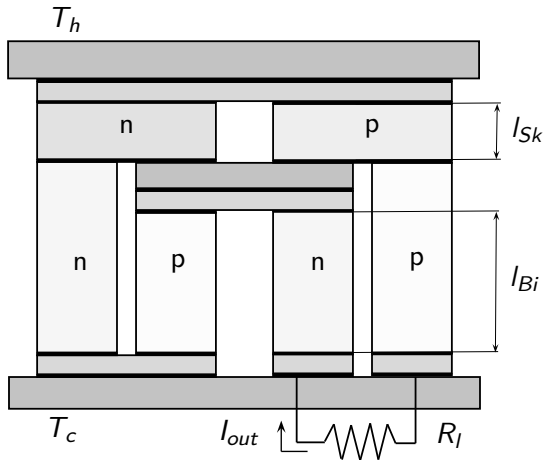


Resultados II

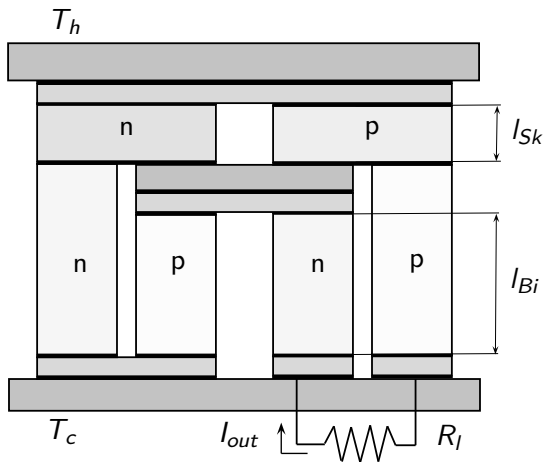


Generador cascada

Geometría



Geometría



η	=	0,028
W	=	83,67 W

Conclusiones

- » Aumento área mejora potencia
- » Campo magnético perjudicial
- » Generador segmentado aumenta eficiencia
- » Optimizar generador cascada

Gracias por su atención
¿Preguntas?