

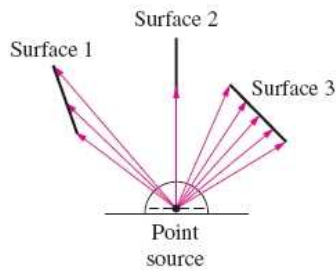
# 13. GAIA

## ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA

### 13.0 - HELBURUAK

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- **Ikuspen-faktorea** definitu, eta erradiazio bidezko bero-transferentziaren kalkuluetan duen garrantzia ulertu.
- Ikuspen-faktorearen erlazioak garatu, eta itxitura bateko **ikuspen-faktore** ezezagunak **kalkulatu**, erlazio horiek erabiliz.
- **Gainazal beltzen** arteko erradiazio bidezko **bero-transferentzia** kalkulatu.
- Itxitura bateko **gainazal difuso eta grisen** arteko erradiazio bidezko bero-transferentzia kalkulatu, **erradiositate** kontzeptuaz baliatuz.
- Bi zonako **itxiturako gainazalen** arteko erradiazio bidezko **bero-transferentziaren abiadura** garbiaren erlazioak lortu, bi xafla paralelo handi, bi zilindro zentrokide luze eta bi esfera zentrokide dituztenak barne.
- **Erradiazio-babesgarriek** bi gainazalen arteko erradiazio bidezko bero-transferentzian duten eragina kuantifikatu, eta erradiazio-efektuak tenperatura-neurketetan duen garrantziaz jabetu.



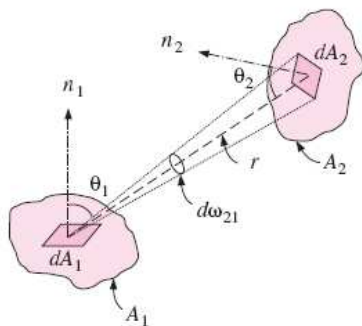
$$Q_{\text{rad}} = f \text{ (orientazioa, propietateak, temperaturak)}$$



**Ikuspen-faktorea ( $F_{ij}$ ;  $F_{i \rightarrow j}$ )**

Forma-faktore, konfigurazio-faktore eta angelu-faktore ere baderitzo.

$F_{ij}$  =  $i$  gainazaletik aiatzen den erradiaziotik  $j$  gainazalera zuzenean iristen den frakzioa.



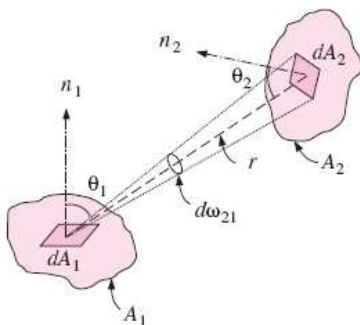
$$\dot{Q}_{dA_1 \rightarrow dA_2} = I_1 \cos \theta_1 dA_1 d\omega_{21}$$

$$\dot{Q}_{dA_1 \rightarrow dA_2} = I_1 \cos \theta_1 dA_1 \frac{dA_2 \cos \theta_2}{r^2}$$

$$\dot{Q}_{A_1 \rightarrow A_2} = \int_{A_2} \int_{A_1} \frac{I_1 \cos \theta_1 \cos \theta_2}{r^2} dA_1 dA_2$$



## 13.1 – IKUSPEN-FAKTOREA



$$\dot{Q}_{dA_1} = J_1 dA_1 = \pi I_1 dA_1$$



**Erradiositatea**

$$\dot{Q}_{A_1} = J_1 A_1 = \pi I_1 A_1$$

$$F_{12} = F_{A_1 \rightarrow A_2} = \frac{\dot{Q}_{A_1 \rightarrow A_2}}{\dot{Q}_{A_1}} = \frac{1}{A_1} \int_{A_2} \int_{A_1} \frac{\cos \theta_1 \cos \theta_2}{\pi r^2} dA_1 dA_2$$

$$F_{21} = F_{A_2 \rightarrow A_1} = \frac{\dot{Q}_{A_2 \rightarrow A_1}}{\dot{Q}_{A_2}} = \frac{1}{A_2} \int_{A_2} \int_{A_1} \frac{\cos \theta_1 \cos \theta_2}{\pi r^2} dA_1 dA_2$$

$$A_1 F_{12} = A_2 F_{21}$$

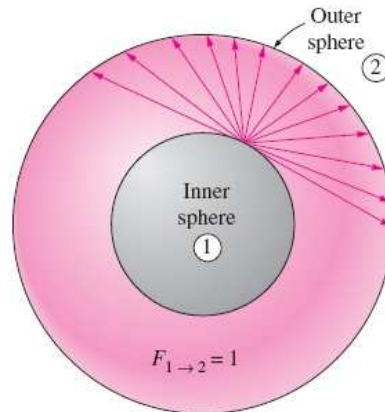
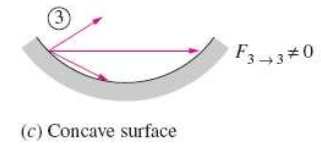
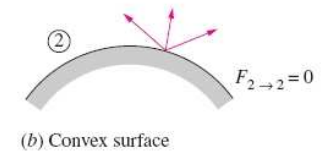
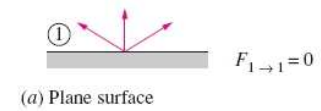
**Elkarrekikotasun-erlazioa**



Baldin  $j = i \rightarrow F_{ii} = i$  gainazaletik abiatu eta gainazal berera zuzenean iristen den erradiazio-frakzioa

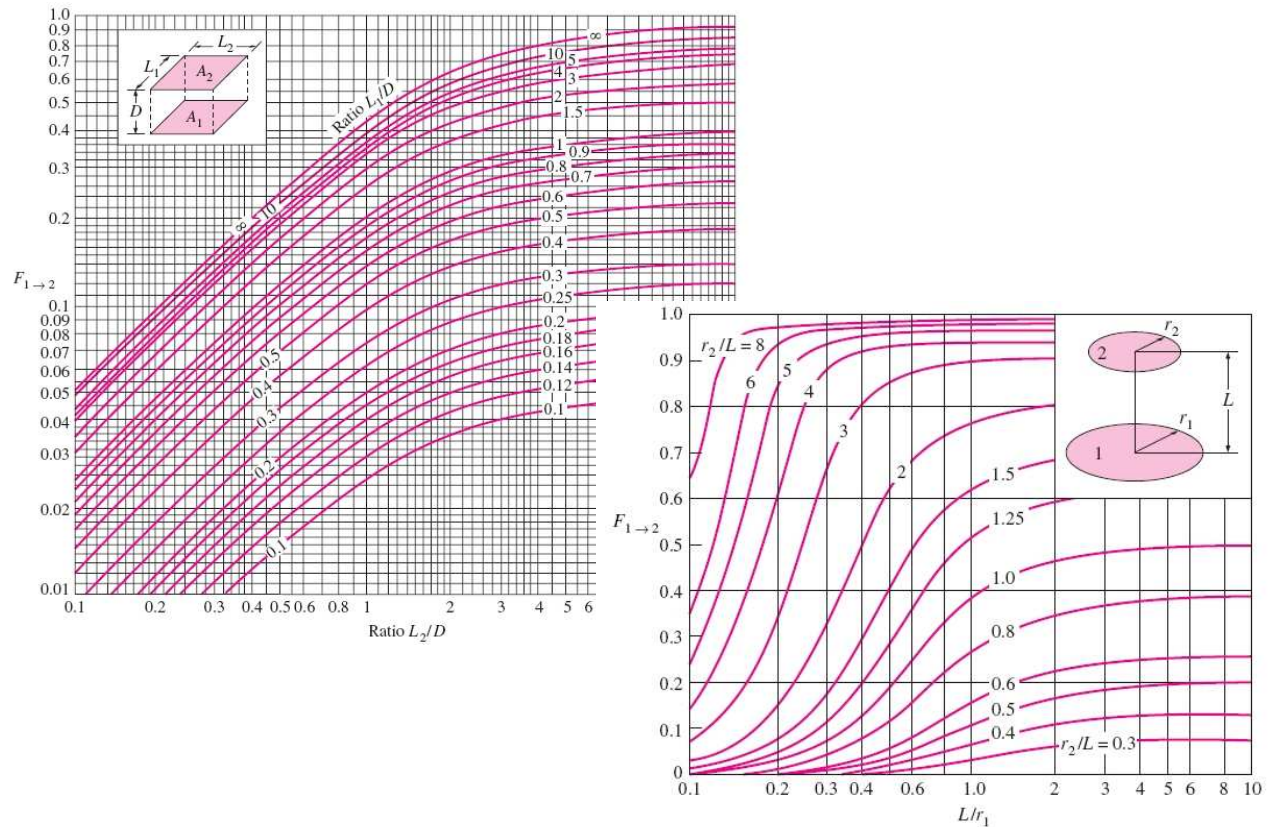
Gainazal lau edo ganbilak  $\rightarrow F_{ii} = 0$

Gainazal ahurrak  $\rightarrow F_{ii} \neq 0$



## 13.1 – IKUSPEN-FAKTOREA

Geometry	Relation	Geometry	Relation
<p>Aligned parallel rectangles</p>	$\bar{X} = X/L \text{ and } \bar{Y} = Y/L$ $F_{i \rightarrow j} = \frac{2}{\pi \bar{X} \bar{Y}} \left\{ \ln \left[ \frac{(1 + \bar{X}^2)(1 + \bar{Y}^2)}{1 + \bar{X}^2 + \bar{Y}^2} \right]^{1/2} + \bar{X}(1 + \bar{Y}^2)^{1/2} \tan^{-1} \frac{\bar{X}}{(1 + \bar{Y}^2)^{1/2}} + \bar{Y}(1 + \bar{X}^2)^{1/2} \tan^{-1} \frac{\bar{Y}}{(1 + \bar{X}^2)^{1/2}} - \bar{X} \tan^{-1} \bar{X} - \bar{Y} \tan^{-1} \bar{Y} \right\}$	<p>Parallel plates with midlines connected by perpendicular line</p>	$W_i = w_i/L \text{ and } W_j = w_j/L$ $F_{i \rightarrow j} = \frac{[(W_i + W_j)^2 + 4]^{1/2} - (W_j - W_i)^2 + 4)^{1/2}}{2W_i}$
<p>Coaxial parallel disks</p>	$R_i = r_i/L \text{ and } R_j = r_j/L$ $S = 1 + \frac{R_j^2}{R_i^2}$ $F_{i \rightarrow j} = \frac{1}{2} \left\{ S - \left[ S^2 - 4 \left( \frac{r_j}{r_i} \right)^2 \right]^{1/2} \right\}$	<p>Inclined plates of equal width and with a common edge</p>	$F_{i \rightarrow j} = 1 - \sin \frac{1}{2} \alpha$
<p>Perpendicular rectangles with a common edge</p>	$H = Z/X \text{ and } W = Y/X$ $F_{i \rightarrow j} = \frac{1}{\pi W} \left\{ W \tan^{-1} \frac{1}{W} + H \tan^{-1} \frac{1}{H} - (H^2 + W^2)^{1/2} \tan^{-1} \frac{1}{(H^2 + W^2)^{1/2}} + \frac{1}{4} \ln \left\{ \frac{(1 + W^2)(1 + H^2)}{1 + W^2 + H^2} \right\} \times \left[ \frac{W^2(1 + W^2 + H^2)}{(1 + W^2)(W^2 + H^2)} \right]^{1/2} \times \left[ \frac{H^2(1 + H^2 + W^2)}{(1 + H^2)(H^2 + W^2)} \right]^{1/2} \right\}$	<p>Perpendicular plates with a common edge</p>	$F_{i \rightarrow j} = \frac{1}{2} \left\{ 1 + \frac{w_j}{w_i} - \left[ 1 + \left( \frac{w_j}{w_i} \right)^2 \right]^{1/2} \right\}$
		<p>Three-sided enclosure</p>	$F_{i \rightarrow j} = \frac{w_i + w_j - w_k}{2w_i}$



## 13.2 – IKUSPEN-FAKTOREAREN ERLAZIOAK

N gainazalez osatutako itxitura  $\rightarrow$   $N^2$  ikuspen-faktore

## 1 – Elkarrekotasun-erlazioa

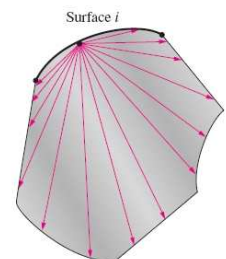
$$A_i F_{ij} = A_j F_{ji}$$

## 2 – Batuketa-araua

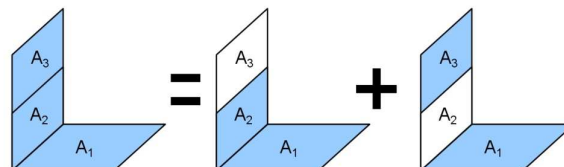
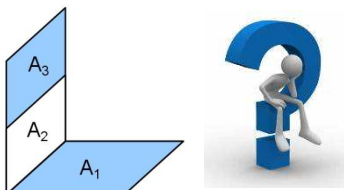
$$\sum_{i=1}^N F_{i \rightarrow j} = 1$$

$$F_{11} + F_{12} + \dots + F_{1N} = 1$$

$$F_{11} + F_{21} + \dots + F_{N1} \neq 1$$



## 3 – Gainjartze-araua



$$F_{1 \rightarrow (2,3)} = F_{1 \rightarrow 2} + F_{1 \rightarrow 3}$$

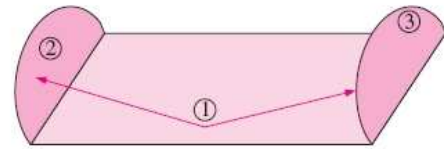
$$F_{1 \rightarrow 3} = F_{1 \rightarrow (2,3)} - F_{1 \rightarrow 2}$$

$$F_{(2,3) \rightarrow 1} = \frac{A_2 F_{2 \rightarrow 1} + A_3 F_{3 \rightarrow 1}}{A_2 + A_3}$$

## 4 – Simetria-araua

j eta k gainazalak i-rekiko simetrikoak  
badira

$$\begin{aligned} F_{i \rightarrow j} &= F_{i \rightarrow k} \\ F_{j \rightarrow i} &= F_{k \rightarrow i} \end{aligned}$$



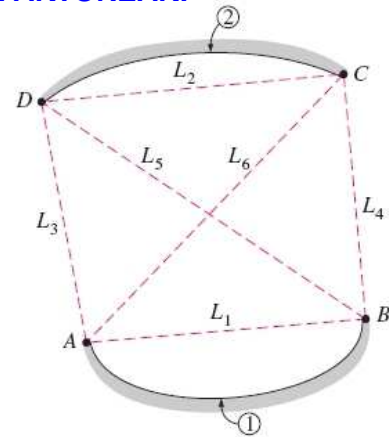
$$F_{1 \rightarrow 2} = F_{1 \rightarrow 3}$$

(Also,  $F_{2 \rightarrow 1} = F_{3 \rightarrow 1}$ )

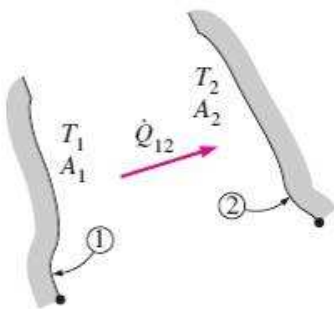
### LUZERA INFINITUKO GAINAZALEN ARTEKO IKUSPEN-FAKTOREAK: HARI GURUTZATUEN METODOA

$$F_{1 \rightarrow 2} = \frac{(L_5 + L_6) - (L_3 + L_4)}{2 \cdot L_1}$$

$$F_{i \rightarrow j} = \frac{\sum (\text{Hari gurutzatuak}) - \sum (\text{Hari gurutzatu gabeak})}{2x(i \text{ gainazaleko haria})}$$



### 13.3 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL BELTZAK



$$\dot{Q}_{1 \rightarrow 2} = \left( \begin{array}{l} 1 \text{ gainazal osotik} \\ \text{irteten den eta 2} \\ \text{gainazalera iristen} \\ \text{den erradiazioa} \end{array} \right) - \left( \begin{array}{l} 2 \text{ gainazal osotik} \\ \text{irteten den eta 1} \\ \text{gainazalera iristen} \\ \text{den erradiazioa} \end{array} \right)$$

$$\dot{Q}_{1 \rightarrow 2} = A_1 \sigma T_1^4 F_{1 \rightarrow 2} - A_2 \sigma T_2^4 F_{2 \rightarrow 1}$$

Elkarrekinkotasun-erlazioa erabilita:  $\dot{Q}_{1 \rightarrow 2} = A_1 F_{1 \rightarrow 2} \sigma (T_1^4 - T_2^4)$

N gainazal beltzek osatutako itxitura batean:

$$\dot{Q}_i = \sum_{j=1}^N \dot{Q}_{i \rightarrow j} = \sum_{j=1}^N A_i F_{i \rightarrow j} \sigma (T_i^4 - T_j^4) \quad [\text{W}]$$

$$\dot{Q}_{i \rightarrow i} =$$

## 13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

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Hipotesiak: Gainazal opakua, difusoa, grisak eta isotermikoak.

Erradiazio propietate uniforme  $\lambda$ -rekiko.

### ERRADIOSITATEA

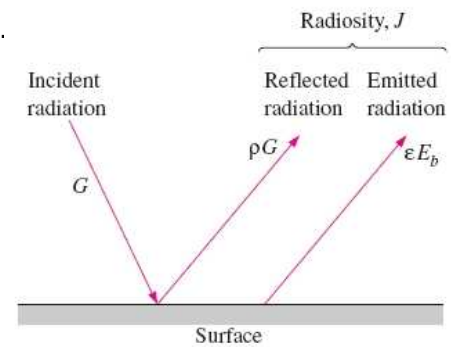
“Gainazal batetik denbora eta azalera unitateko irteten den erradiazio-energia”

$$J_i = \left( \begin{array}{c} i \text{ gainazalak} \\ \text{igorritako} \\ \text{erradiazioa} \end{array} \right) + \left( \begin{array}{c} i \text{ gainazalak} \\ \text{islatutako} \\ \text{erradiazioa} \end{array} \right)$$

$$J_i = \varepsilon_i \cdot E_{bi} + \rho_i \cdot G_i$$

$$\left. \begin{array}{l} \text{Gainazal grisa} \rightarrow \varepsilon_i = \alpha_i \\ \text{Gainazal opakua} \rightarrow \alpha_i + \rho_i = 1 \end{array} \right\} \Rightarrow J_i = \varepsilon_i \cdot E_{bi} + (1 - \varepsilon_i) \cdot G_i \quad [\text{W/m}^2]$$

Gorputz beltz batean:  $J_{bi} = E_{bi} = \sigma \cdot T_i^4$



## 13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

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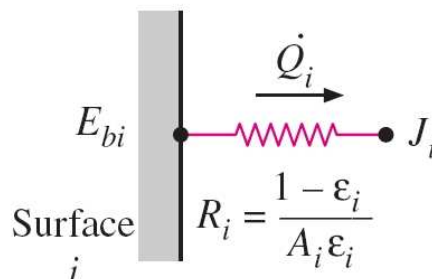
### ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA GARBIA

$$\dot{Q}_i = \left( \begin{array}{c} i \text{ gainazal osotik} \\ \text{irteten} \\ \text{den erradiazioa} \end{array} \right) - \left( \begin{array}{c} i \text{ gainazal osora} \\ \text{iristen} \\ \text{den erradiazioa} \end{array} \right)$$

$$\dot{Q}_i = A_i (J_i - G_i) = A_i \left( J_i - \frac{J_i - \varepsilon_i E_{bi}}{1 - \varepsilon_i} \right) = \frac{A_i \varepsilon_i}{1 - \varepsilon_i} (E_{bi} - J_i)$$

Ohm-en legearen araberako analogia eginez:

$$\dot{Q}_i = \frac{E_{bi} - J_i}{R_i}$$





## 13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

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### ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA GARBIA

$$\dot{Q}_i = \frac{E_{bi} - J_i}{R_i}$$

$$R_i = \frac{1 - \varepsilon_i}{A_i \varepsilon_i}$$

Erradiazio gainazal erresistentzia

Gorpuzt beltz batean?



Gainazal adiabatikoa:



Gainazalak irabazten duen adina erradiazio-energia galtzen du

$$\dot{Q}_i = 0$$



Gainazal berrerradiatzaile

Egoera egonkorrean eta konbektzio mesprezagarriarekin

$$J_i = E_{bi} = \sigma T_i^4$$

TERMOTEKNIKIA

## 13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

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### BI GAINAZALEN ARTEKO ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA

$$\dot{Q}_{i \rightarrow j} = \left[ \begin{array}{l} i \text{ gainazal osotik irteten} \\ \text{den eta } j \text{ gainazalera} \\ \text{iristen den erradiazioa} \end{array} \right] - \left[ \begin{array}{l} j \text{ gainazal osotik irteten} \\ \text{den eta } i \text{ gainazalera} \\ \text{iristen den erradiazioa} \end{array} \right]$$

$$\dot{Q}_{i \rightarrow j} = A_i J_i F_{i \rightarrow j} - A_j J_j F_{j \rightarrow i} \quad [\text{W}]$$

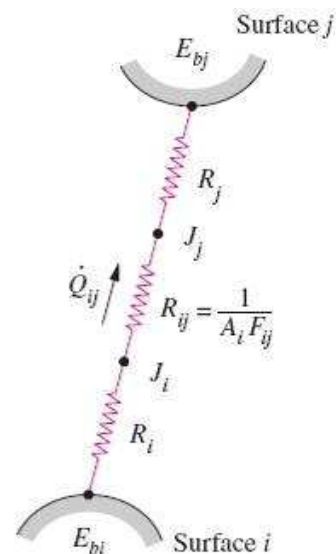
Elkarrekikotasun-erlazioa erabilita:  $\dot{Q}_{i \rightarrow j} = A_i F_{i \rightarrow j} (J_i - J_j)$

Ohmen legearen analogia eginda:

$$\dot{Q}_{i \rightarrow j} = \frac{J_i - J_j}{R_{i \rightarrow j}} \quad [\text{W}]$$

$$R_{i \rightarrow j} = \frac{1}{A_i F_{i \rightarrow j}}$$

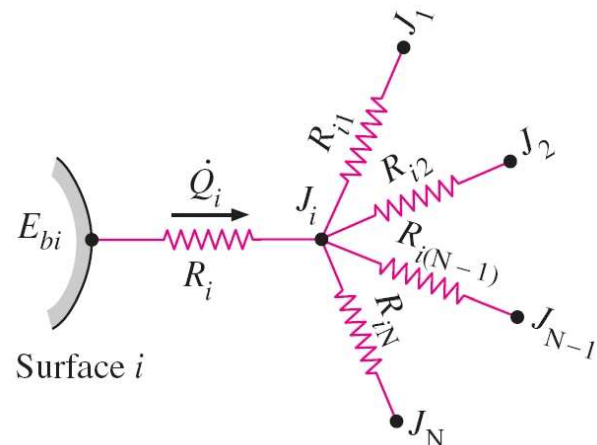
Espazio-erresistentzia



## BI GAINAZALEN ARTEKO ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA

$$\dot{Q}_i = \sum_{j=1}^N \dot{Q}_{i \rightarrow j} = \sum_{j=1}^N A_i F_{i \rightarrow j} (J_i - J_j)$$

$$\dot{Q}_i = \sum_{j=1}^N \frac{J_i - J_j}{R_{i \rightarrow j}} \quad [\text{W}]$$



$$\frac{E_{bi} - J_i}{R_i} = \sum_{j=1}^N \frac{J_i - J_j}{R_{i \rightarrow j}} \quad [\text{W}]$$

## ERRADIAZIO PROBLEMAK EBAZTEKO METODOAK

Gainazal bakoitzaren tenperatura  $T_i$  edo bero-transferentziaren abiadura garbia  $\dot{Q}_i$  eman behar dira.

### Metodo zuzena (*matriziala*)

$\dot{Q}_i$  bero-transferentziaren abiadura garbia zehaztua duten gainazaletan:

$$\dot{Q}_i = A_i \sum_{j=1}^N F_{i \rightarrow j} (J_i - J_j)$$

$T_i$  tenperatura zehaztua duten gainazaletan:

$$\sigma \cdot T_i^4 = J_i + \frac{1 - \epsilon_i}{\epsilon_i} \sum_{j=1}^N F_{i \rightarrow j} (J_i - J_j)$$

N ekuazio eta N ezezagunez osatutako sistema ( $J_1, J_2, \dots, J_N$ )

### Sare-metodoa

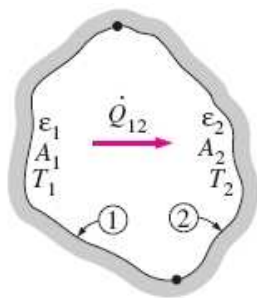
Sare elektrikoen analogian oinarrituta



## 13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

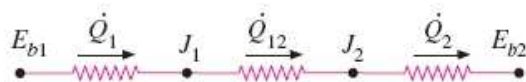
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### ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA BI GAINAZALEKO ITXITURETAN



$$\dot{Q}_{12} = \dot{Q}_1 = -\dot{Q}_2$$

$$\dot{Q}_{12} = \frac{E_{b1} - E_{b2}}{R_1 + R_{12} + R_2}$$



$$R_1 = \frac{1 - \epsilon_1}{A_1 \epsilon_1} \quad R_{12} = \frac{1}{A_1 F_{12}} \quad R_2 = \frac{1 - \epsilon_2}{A_2 \epsilon_2}$$

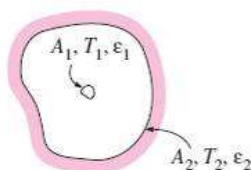
$$\dot{Q}_{12} = \frac{\sigma \cdot (T_1^4 - T_2^4)}{\frac{1 - \epsilon_1}{A_1 \epsilon_1} + \frac{1}{A_1 F_{12}} + \frac{1 - \epsilon_2}{A_2 \epsilon_2}}$$

## 13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

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### ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA BI GAINAZALEKO ITXITURETAN

Small object in a large cavity

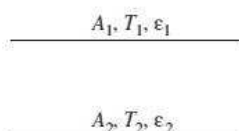


$$\frac{A_1}{A_2} \approx 0$$

$$F_{12} = 1$$

$$\dot{Q}_{12} = A_1 \sigma \epsilon_1 (T_1^4 - T_2^4)$$

Infinitely large parallel plates

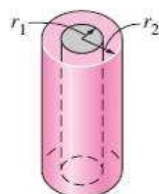


$$A_1 = A_2 = A$$

$$F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A \sigma (T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

Infinitely long concentric cylinders



$$\frac{A_1}{A_2} = \frac{r_1}{r_2}$$

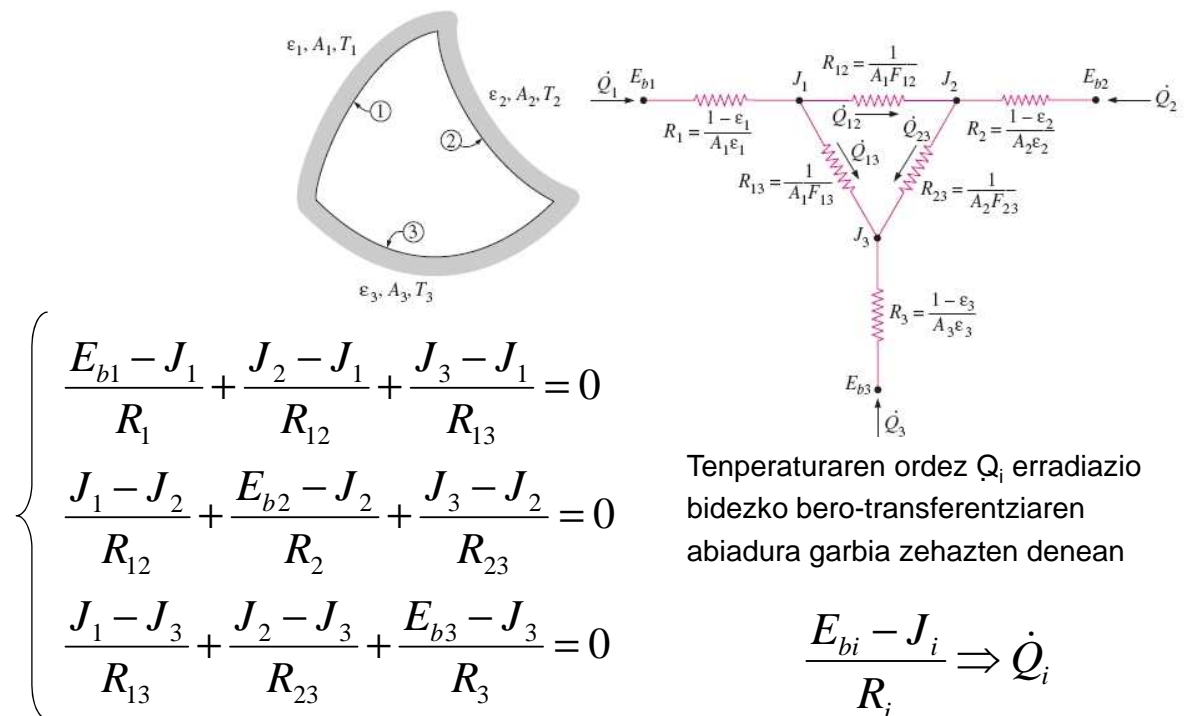
$$F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A_1 \sigma (T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1 - \epsilon_2}{\epsilon_2} \left( \frac{r_1}{r_2} \right)}$$

## 13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

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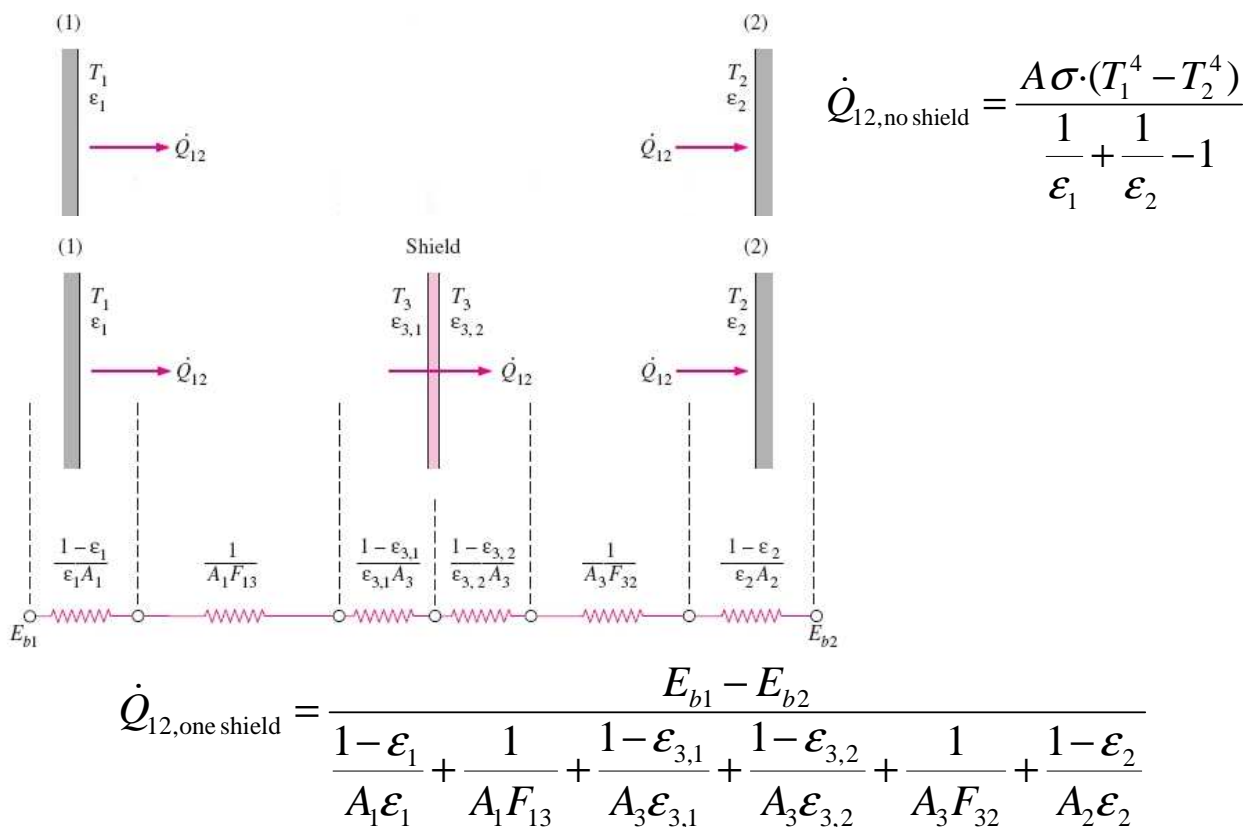
### ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA HIRU GAINAZALEKO ITXITURETAN

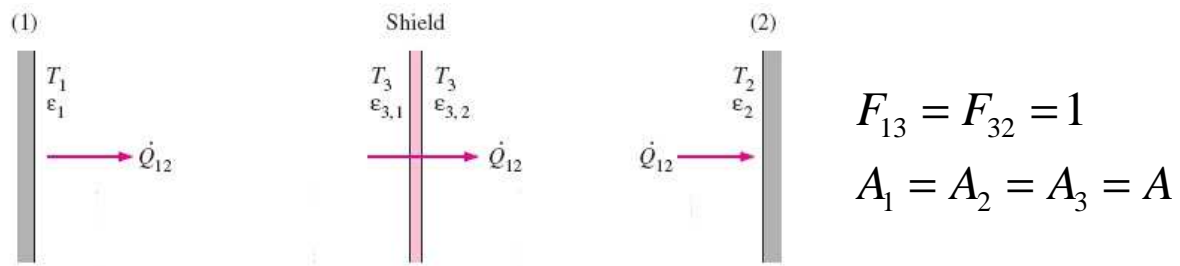


Temperaturaren ordeaz  $\dot{Q}_i$  erradiazio bidezko bero-transferentziaren abiadura garbia zehazten denean

$$\frac{E_{bi} - J_i}{R_i} \Rightarrow \dot{Q}_i$$

## 13.5 – ERRADIAZIO-BABESGARRIAK ETA ERRADIAZIO-EFEKTUAK 20/30



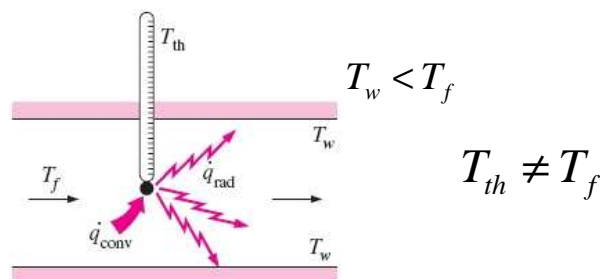


$$\dot{Q}_{12, \text{one shield}} = \frac{A\sigma \cdot (T_1^4 - T_2^4)}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right)}$$

$$\dot{Q}_{12, N \text{ shields}} = \frac{A\sigma \cdot (T_1^4 - T_2^4)}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right) + \dots + \left(\frac{1}{\varepsilon_{N,1}} + \frac{1}{\varepsilon_{N,2}} - 1\right)}$$

$$\varepsilon_1 = \varepsilon_2 = \dots = \varepsilon_{N,1} = \varepsilon_{N,2} = \varepsilon \Rightarrow \dot{Q}_{12, N \text{ shields}} = \frac{A\sigma \cdot (T_1^4 - T_2^4)}{(N+1)\left(\frac{1}{\varepsilon} + \frac{1}{\varepsilon} - 1\right)} = \frac{1}{N+1} \dot{Q}_{12, \text{no shield}}$$

### ERRADIAZIOAREN ERAGINA TENPERATURA-NEURKETETAN



Orekan:

$$h \cdot (T_f - T_{th}) = \varepsilon_{th} \sigma (T_{th}^4 - T_w^4)$$

$$T_f = T_{th} + \frac{\varepsilon_{th} \sigma (T_{th}^4 - T_w^4)}{h} \quad [\text{K}]$$

Hutsean, Ar, He, O<sub>2</sub> eta N<sub>2</sub> → Erradiazio termikoarekiko gardenak.

H<sub>2</sub>O, CO<sub>2</sub>, CO, SO<sub>2</sub> y H<sub>n</sub>C<sub>m</sub>

→ Erradiazio prozesuetan parte hartu. Absortzioa tenperatura ertainetan eta absortzioa eta igorpena tenperatura altuetan.

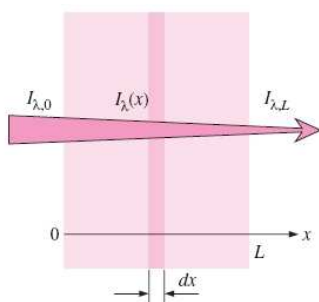
Errekuntza-gasak

### Zailtasunak

- Gas-erradiazioa fenomeno bolumetrikoa da.
- Gasek zenbait uhin-luzera tarte estuetan igortzen eta xurgatzen dute erradiazioa.
- Gas-nahaste bateko osagaien igortze- eta xurgatze-ezaugarriak ere tenperaturaren, presioaren eta gas-nahasturaren konposizioaren araberakoak dira.

## 13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

### INGURUNE PARTE-HARTZAILE BATEN ERRADIAZIO-PROPIETATEAK



$$dI_{\lambda}(x) = -\kappa_{\lambda} I_{\lambda}(x) dx$$

Beer-en legea

Absortzio espektralaren koefizienteak [m<sup>-1</sup>]

$$\frac{I_{\lambda,L}}{I_{\lambda,0}} = e^{-\kappa_{\lambda} L} = \tau_{\lambda}$$

Transmisibitate espektrala

Dispertzatzen ez duten inguruak ( $\rho = 0$ )  $\alpha_{\lambda} + \tau_{\lambda} = 1$

Absortzio espektrala

$$\alpha_{\lambda} = 1 - e^{-\kappa_{\lambda} L}$$

Emisibitate espektrala

$$\varepsilon_{\lambda} = \alpha_{\lambda} = 1 - e^{-\kappa_{\lambda} L}$$

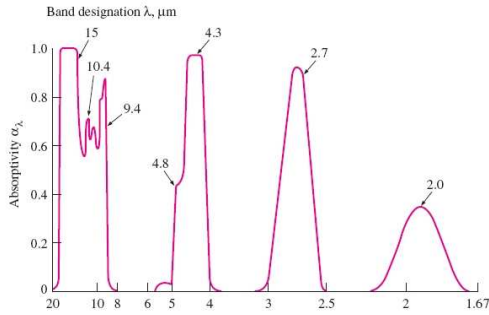
Baldin  $\kappa_{\lambda} L \uparrow \rightarrow \varepsilon_{\lambda} \approx \alpha_{\lambda} \approx 1$

Ingurune optikoki lodia  $\equiv$  Gainazal beltza

# 13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

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## GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

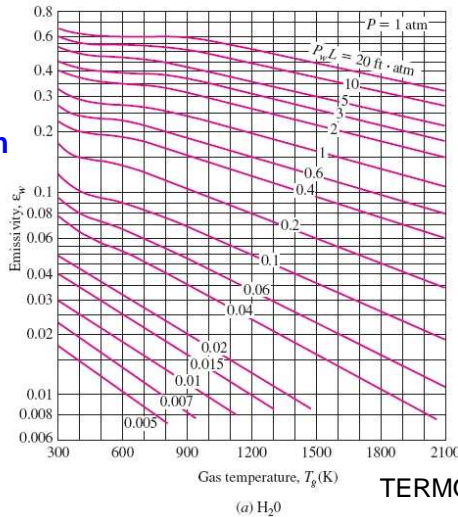


Absortzioaren banda-izaera → Ez-grisa

Bi metodo:

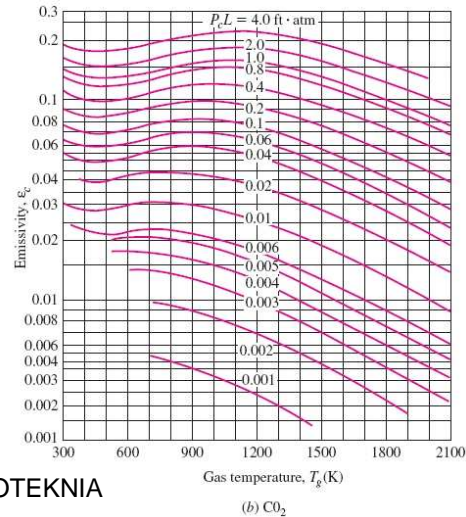
- 1) Banda-eredua
- 2) Gas gris baten absortibitate eta emisibitate erangikorrek kalkulatu.

**H<sub>2</sub>O**  
**P<sub>T</sub> = 1 atm**



TERMOTEKNIKIA

**CO<sub>2</sub>**  
**P<sub>T</sub> = 1 atm**

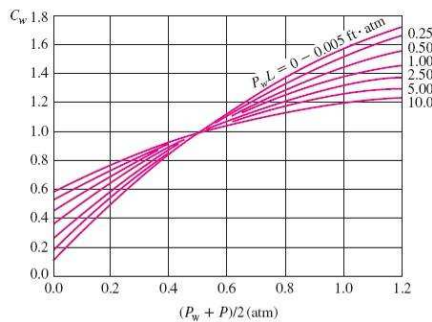


# 13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

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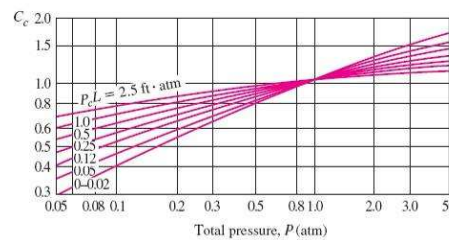
## GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

**H<sub>2</sub>O**  
**P<sub>T</sub> ≠ 1 atm**

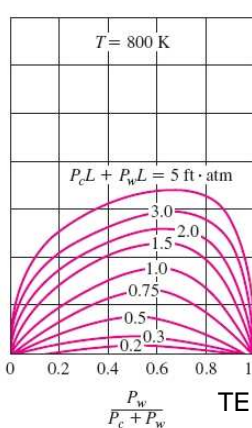
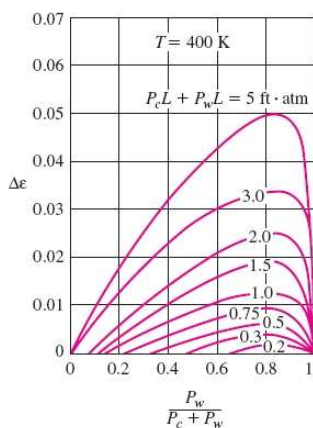


$$\epsilon_w = C_w \cdot \epsilon_{w,1atm}$$

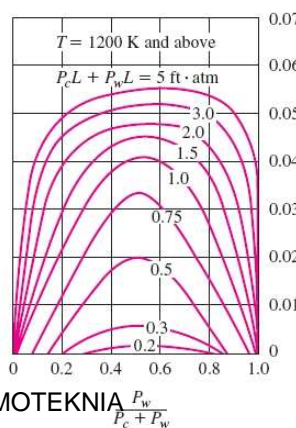
**CO<sub>2</sub>**  
**P<sub>T</sub> ≠ 1 atm**



$$\epsilon_c = C_c \cdot \epsilon_{c,1atm}$$



TERMOTEKNIKIA



$$\epsilon_g = \epsilon_w + \epsilon_c - \Delta\epsilon$$

Factor corrector de  
la emisividad



## 13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

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### GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

Geometria ez hemisferikoetan → Batez besteko izpi luzera  $L$

Mean beam length  $L$  for various gas volume shapes

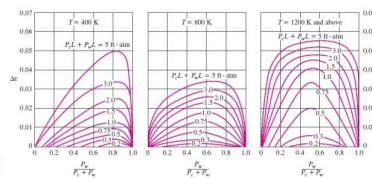
Gas Volume Geometry	$L$
Hemisphere of radius $R$ radiating to the center of its base	$R$
Sphere of diameter $D$ radiating to its surface	$0.65D$
Infinite circular cylinder of diameter $D$ radiating to curved surface	$0.95D$
Semi-infinite circular cylinder of diameter $D$ radiating to its base	$0.65D$
Semi-infinite circular cylinder of diameter $D$ radiating to center of its base	$0.90D$
Infinite semicircular cylinder of radius $R$ radiating to center of its base	$1.26R$
Circular cylinder of height equal to diameter $D$ radiating to entire surface	$0.60D$
Circular cylinder of height equal to diameter $D$ radiating to center of its base	$0.71D$
Infinite slab of thickness $D$ radiating to either bounding plane	$1.80D$
Cube of side length $L$ radiating to any face	$0.66L$
Arbitrary shape of volume $V$ and surface area $A_s$ radiating to surface	$3.6V/A_s$

## 13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

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### GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

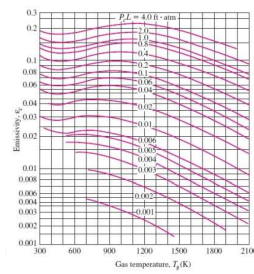
$$\alpha_g = \alpha_w + \alpha_c - \Delta\alpha$$



$$\Delta\alpha = \Delta\epsilon$$

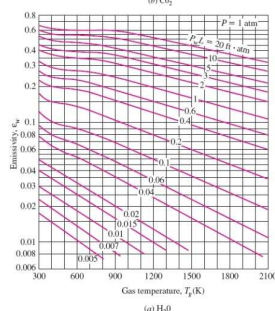
$$T_s$$

CO<sub>2</sub>



$$\alpha_c = C_c \cdot \left( \frac{T_g}{T_s} \right)^{0.65} \cdot \epsilon_c(T_s, P_c L \frac{T_s}{T_g})$$

H<sub>2</sub>O




$$\alpha_w = C_w \cdot \left( \frac{T_g}{T_s} \right)^{0.45} \cdot \epsilon_w(T_s, P_w L \frac{T_s}{T_g})$$



### GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

Gas batek gainazalera igorritakoa

Gas batek xurgatutakoa gainazala beltza izanik

$$\dot{Q}_{g,e} = \varepsilon_g A_S \sigma T_g^4 \qquad \dot{Q}_{g,a} = \alpha_g A_S \sigma T_S^4$$


$$\dot{Q}_{net,black} = A_S \sigma (\varepsilon_g T_g^4 - \alpha_g T_S^4)$$

Gainazala beltza ez balitz ( $\varepsilon > 0,7$ )

$$\dot{Q}_{net,gray} = \frac{1 + \varepsilon_s}{2} \dot{Q}_{net,black} = \frac{1 + \varepsilon_s}{2} A_S \sigma (\varepsilon_g T_g^4 - \alpha_g T_S^4)$$