

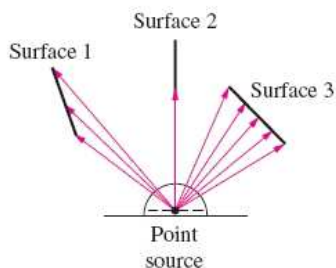
13. GAIA

ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA

13.0 - HELBURUAK

2/30

- **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, **erradiositaterik** 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 temperatura-neurketetan duen garrantziaz jabetu
- **Gainazal gris eta gas igoerle eta xurgatzaileen** arteko erradiazio bidezko **bero-transferentzia** kalkulatu.



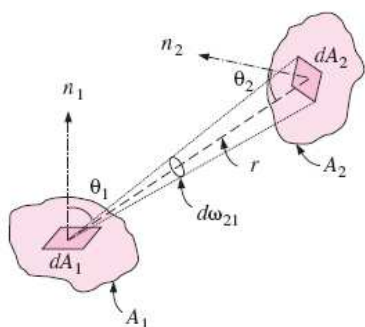
$$Q_{\text{rad}} = f \text{ (orientazioa, propietateak, tenperaturak)}$$



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

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

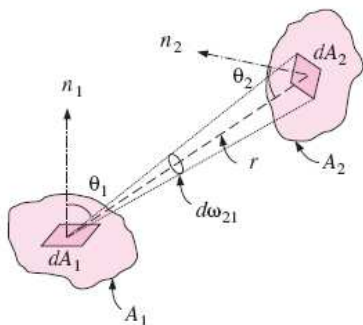
F_{ij} = *i* gainazaletik abiatzen den erradiazioetik *j* gainazalera zuzenean iristen den frakzioa.



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

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

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



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

Erradiositatea

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

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

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

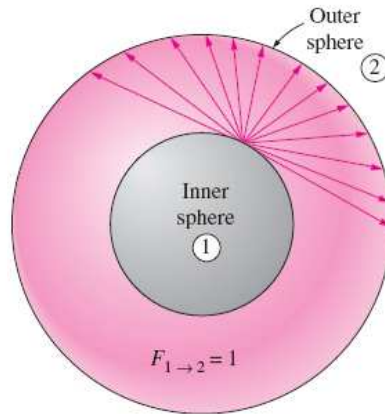
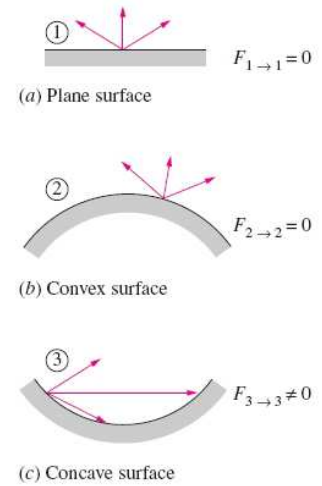
$$A_1 F_{12} = A_2 F_{21}$$

Elkarrekotasun-erlazioa

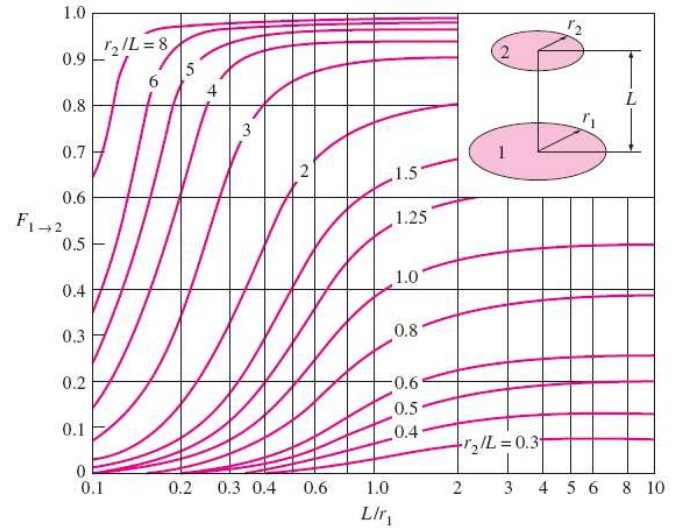
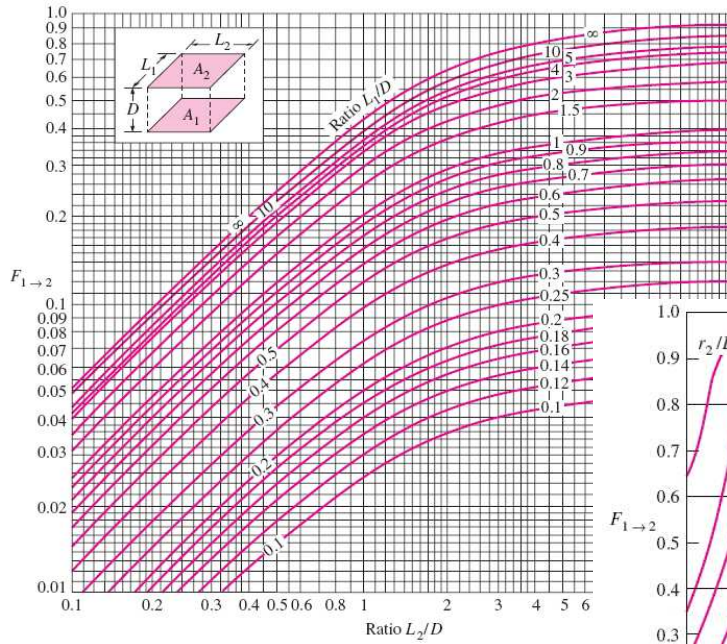
Baldin $j = i \rightarrow F_{ii} = i$ gainazaletik abiatu eta gainazal berera zuzenean iristen den erradiazio-frakzioa

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

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



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



13.2 – IKUSPEN-FAKTOREAREN ERLAZIOAK

N gainazalez osatutako itxitura → N² ikuspen-faktore

1 – Elkarrekotasun-erlazioa

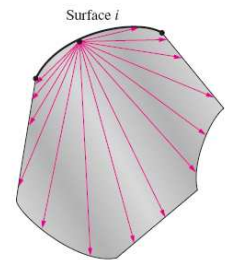
$$A_i F_{ij} = A_j F_{ji}$$

2 – Batuketa-araua

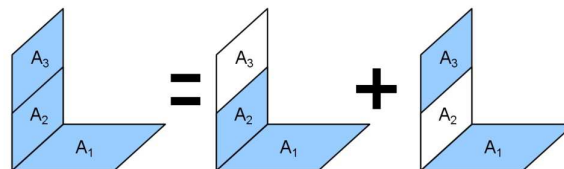
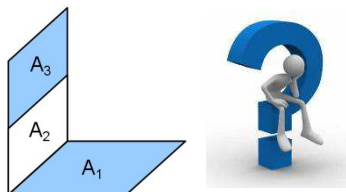
$$\sum_{j=1}^N F_{i \to j} = 1$$

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

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



3 – Gainjartze-araua



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

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

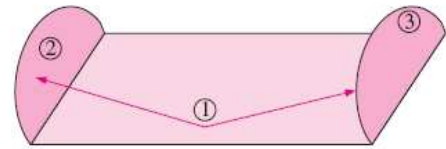
$$F_{(2,3) \to 1} = \frac{A_2 F_{2 \to 1} + A_3 F_{3 \to 1}}{A_2 + A_3}$$

4 – Simetria-araua

j eta k gainazalak i-rekiko simetrikoak badira

$$F_{i \rightarrow j} = F_{i \rightarrow k}$$

$$F_{j \rightarrow i} = F_{k \rightarrow i}$$

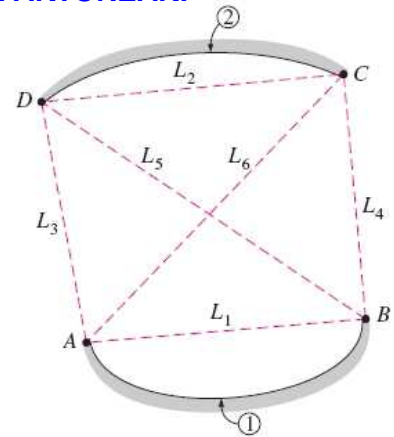


$F_{1 \rightarrow 2} = F_{1 \rightarrow 3}$
(Also, $F_{2 \rightarrow 1} = F_{3 \rightarrow 1}$)

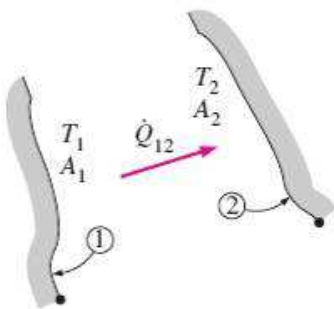
LUZERA INFINITUKO GAINAZALEN ARTEKO IKUSPEN-FAKTOREAK: HARI GURUTZATUEN METODOA

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

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



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 itxura 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

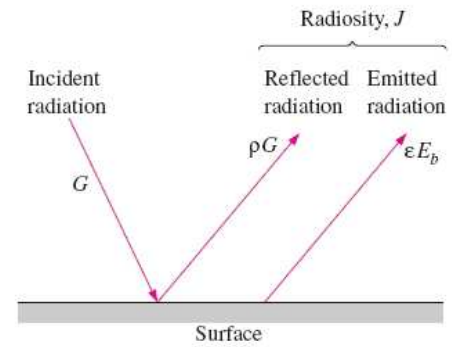
Hipotesiak: Gainazal opakuak, difusoak, grisak eta isotermikoak.

Erradiazio uniformea.

ERRADIOSITATEA

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

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



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

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

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

13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

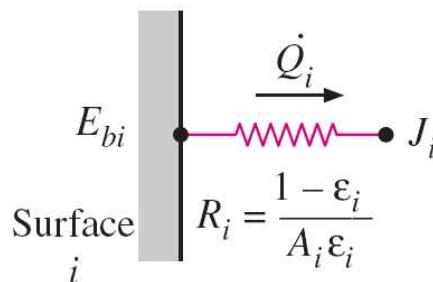
ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA NETOA:

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

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

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

ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA NETOA: $\dot{Q}_i = \frac{E_{bi} - J_i}{R_i}$

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

Erradiazio gainazal erresistentzia

Gorpuzt beltz batean?



Gainazal berrerradiatzailea → Gainazalak irabazten duen adina erradiazio-energia galtzen du → $\dot{Q}_i = 0$

Egoera egonkorrean eta konbektzio mesprezagarriarekin

↓
Gainazal adiabatikoa

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

TERMOTEKNIA

13.4 – ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA: GAINAZAL DIFUSO GRISAK

BI GAINAZALEN ARTEKO ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA

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

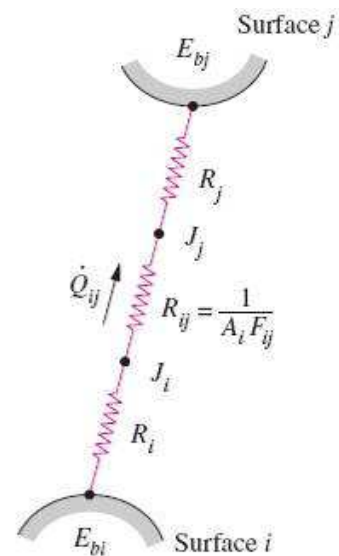
$$\dot{Q}_{i \rightarrow j} = A_i J_i F_{i \rightarrow j} - A_j J_j F_{j \rightarrow i} \quad [\text{W}]$$

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

Ohmen legearen analogia eginda:

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

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

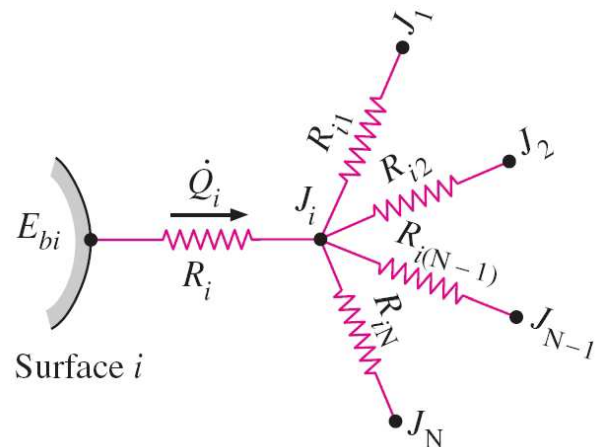


Espazio-erresistentzia

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 netoa \dot{Q}_i eman behar dira.

Metodo zuzena (*matriziala*)

\dot{Q}_i bero-transferentziaren abiadura netoa 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:

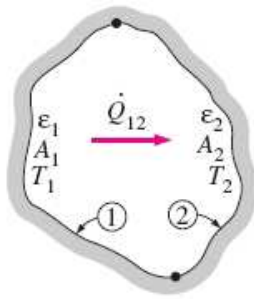
$$\sigma \cdot T_i^4 = J_i + \frac{1 - \epsilon_i}{\epsilon_i} \sum_{j=1}^N F_{i \rightarrow j} (J_i - J_j)$$

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

Sare-metodoa

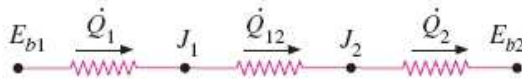
Sare elektrikoan analogian oinarrituta

ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA BI GAINAZALEKO ITXITURETAN



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

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

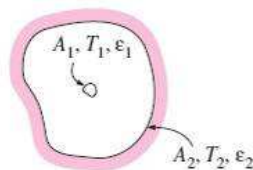


$$R_1 = \frac{1 - \epsilon_1}{A_1 \epsilon_1} \quad R_{12} = \frac{1}{A_1 F_{12}} \quad R_2 = \frac{1 - \epsilon_2}{A_2 \epsilon_2}$$

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

ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA BI GAINAZALEKO ITXITURETAN

Small object in a large cavity

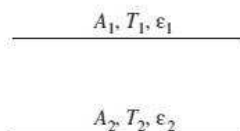


$$\frac{A_1}{A_2} \approx 0$$

$$F_{12} = 1$$

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

Infinitely large parallel plates

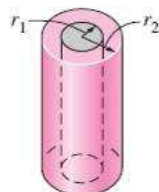


$$A_1 = A_2 = A$$

$$F_{12} = 1$$

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

Infinitely long concentric cylinders

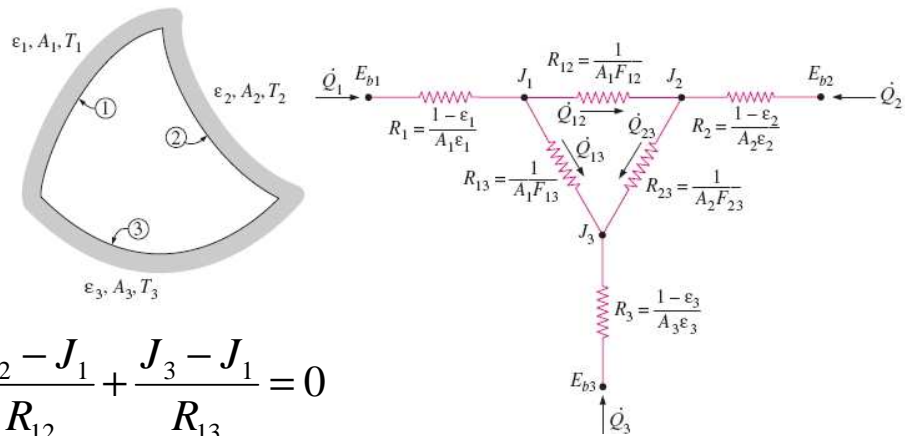


$$\frac{A_1}{A_2} = \frac{r_1}{r_2}$$

$$F_{12} = 1$$

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

ERRADIAZIO BIDEZKO BERO-TRANSFERENTZIA HIRU GAINAZALEKO ITXITURETAN

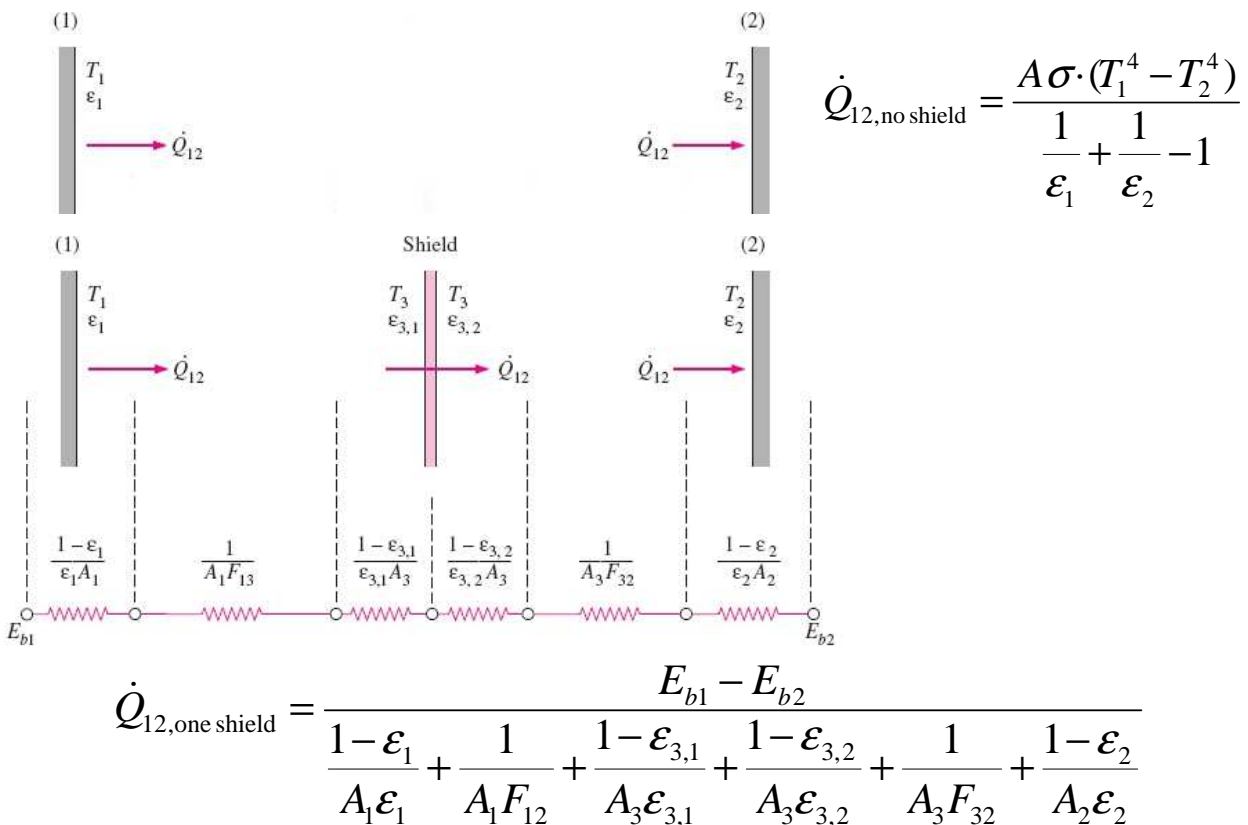


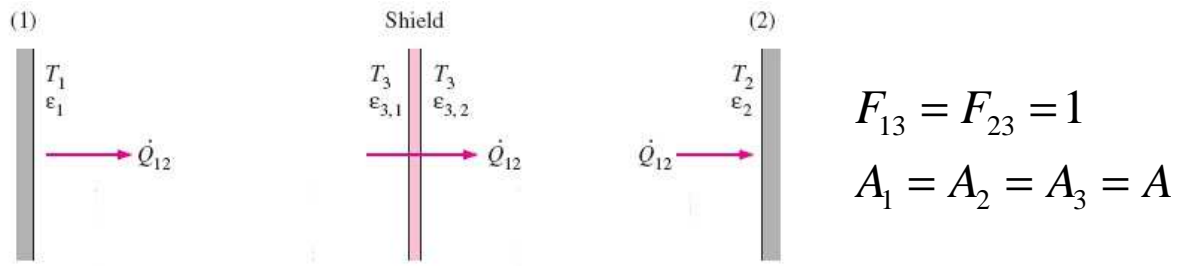
$$\begin{cases} \frac{E_{b1} - J_1}{R_1} + \frac{J_2 - J_1}{R_{12}} + \frac{J_3 - J_1}{R_{13}} = 0 \\ \frac{J_1 - J_2}{R_{12}} + \frac{E_{b2} - J_2}{R_2} + \frac{J_3 - J_2}{R_{23}} = 0 \\ \frac{J_1 - J_3}{R_{13}} + \frac{J_2 - J_3}{R_{23}} + \frac{E_{b3} - J_3}{R_3} = 0 \end{cases}$$

Temperaturaren ordean 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



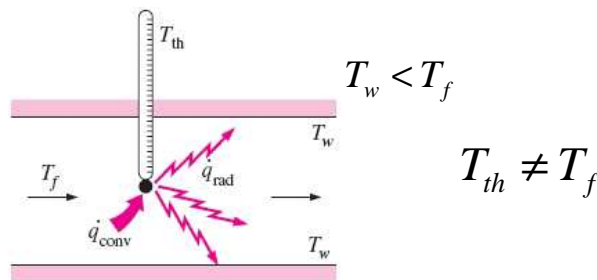


$$\dot{Q}_{12, \text{one shield}} = \frac{A\sigma \cdot (T_1^4 - T_2^4)}{\left(\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1\right) + \left(\frac{1}{\epsilon_{3,1}} + \frac{1}{\epsilon_{3,2}} - 1\right)}$$

$$\dot{Q}_{12, N \text{ shields}} = \frac{A\sigma \cdot (T_1^4 - T_2^4)}{\left(\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1\right) + \left(\frac{1}{\epsilon_{3,1}} + \frac{1}{\epsilon_{3,2}} - 1\right) + \dots + \left(\frac{1}{\epsilon_{N,1}} + \frac{1}{\epsilon_{N,2}} - 1\right)}$$

$$\epsilon_1 = \epsilon_2 = \dots = \epsilon_{N,1} = \epsilon_{N,2} = \epsilon \Rightarrow \dot{Q}_{12, N \text{ shields}} = \frac{A\sigma \cdot (T_1^4 - T_2^4)}{(N+1)\left(\frac{1}{\epsilon} + \frac{1}{\epsilon} - 1\right)} = \frac{1}{N+1} \dot{Q}_{12, \text{no shield}}$$

ERRADIAZIOAREN ERAGINA TEMPERATURA-NEURKETETAN



Orekan:

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

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

Hutsean, Ar, He, O₂ eta N₂ → Erradiazio termikoarekiko gardenak.

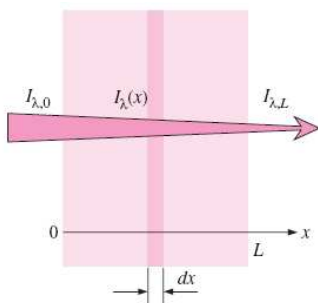
H₂O, CO₂, CO, SO₂ y H_nC_m → Erradiazio prozesuetan parte hartu. Absortzioa tenperatura ertainetan eta absortzioa eta igorpena tenperatura altuetan.

↓
Errekuntza-gasak

Zailtasunak

- Gas-erradiazioa fenomeno bolumentrikoa 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 araberrakoak dira.

INGURUNE PARTE-HARTZAILE BATEN ERRADIAZIO-PROPIETATEAK



$$dI_\lambda(x) = -k_\lambda I_\lambda(x) dx \quad \text{Beer-en legea}$$

Absortzio espektralaren koefizienteak [m⁻¹]

$$\frac{I_{\lambda,L}}{I_{\lambda,0}} = e^{-k_\lambda L} = \tau_\lambda \quad \text{Transmisibitate espektrala}$$

Dispertzatzen ez duten inguruak (ρ = 0) $\alpha_\lambda + \tau_\lambda = 1$

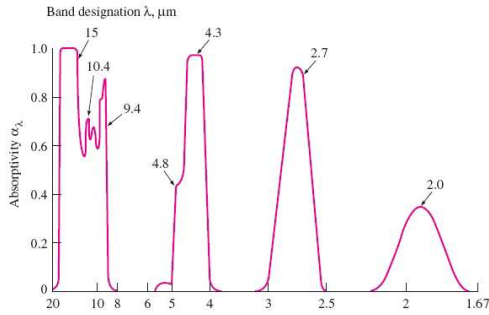
Absortzio espektrala $\alpha_\lambda = 1 - e^{-k_\lambda L}$

Emisibitate espektrala $\epsilon_\lambda = \alpha_\lambda = 1 - e^{-k_\lambda L}$

Baldin $k_\lambda L \uparrow \rightarrow \epsilon_\lambda \approx \alpha_\lambda \approx 1$ Ingurune optikoki lodia ≡ Gainazal beltza

13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

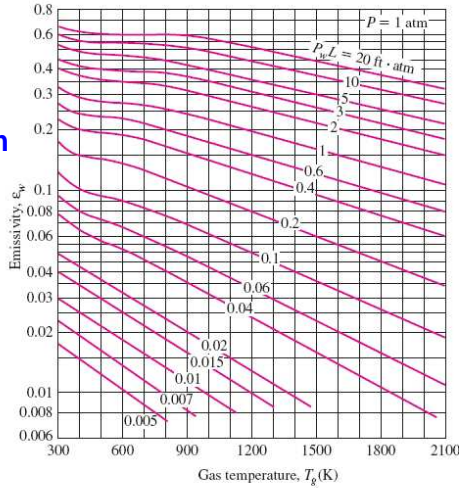


Absortzioaren banda-izaera → Ez-grisa

Bi metodo:

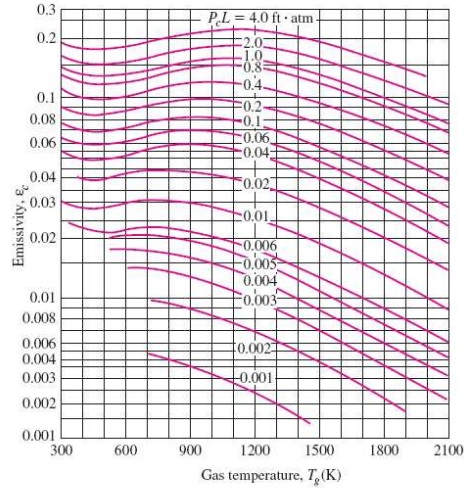
- 1) Banda-eredua
- 2) Gas gris baten absortibitate eta emisibitate erangikorak kalkulatu.

H₂O
P_T = 1 atm



(a) H₂O

CO₂
P_T = 1 atm

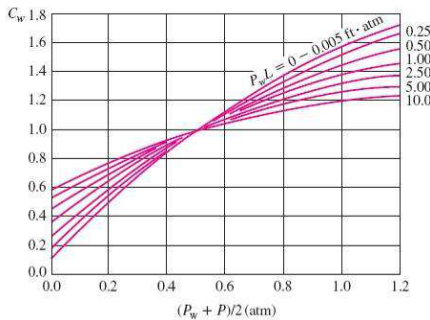


(b) CO₂

13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

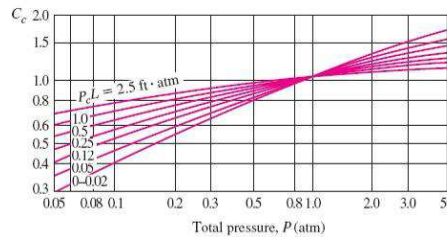
GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

H₂O
P_T ≠ 1 atm

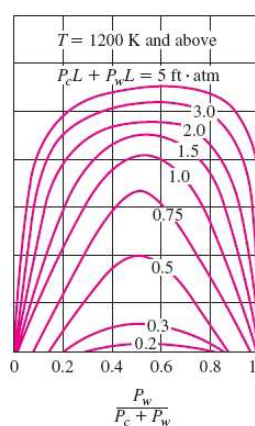
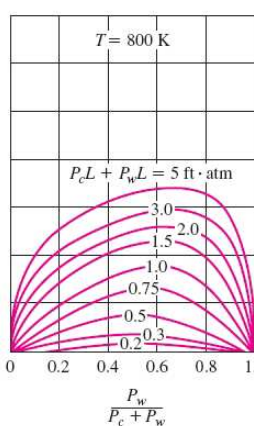
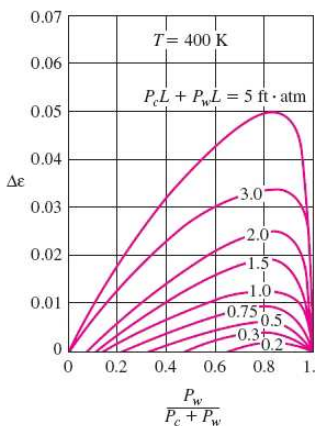


$$\epsilon_w = C_w \cdot \epsilon_{w,1atm}$$

CO₂
P_T ≠ 1 atm



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



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

Emisibitatearen zuzenketa faktorea

13.6 – ERRADIAZIO-TRUKEA GAS IGORLEEKIN ETA XURGATZAILEEKIN

GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

Geometria ez hemisferikoetan → Batez besteko izpi luzera L

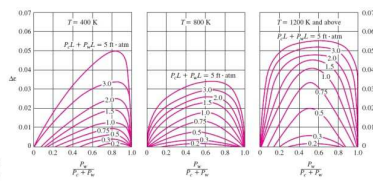
Mean beam length L for various gas volume shapes

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

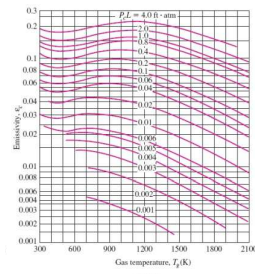
GASEN ETA GAS-NAHASTEEN EMISIBITATEA ETA ABSORTIBITATEA

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



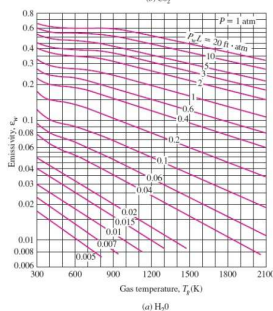
$$\Delta\alpha = \Delta\varepsilon_{T_S}$$

CO₂



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

H₂O




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

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 ($\varepsilon > 0,7$)

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