KURS ZA ENERGETSKI AUDIT 1.2

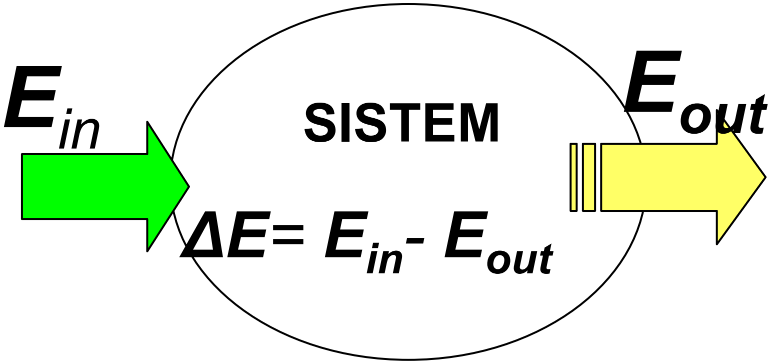
TEORIJSKE OSNOVE

Pripremio: Dr Nenad Kažić

I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

Prema Zakonu o održanju energije, promjena energije (*ΔE*) neizolovanog sistema jednaka je "čistom" (neto) protoku energije kroz njegove granice

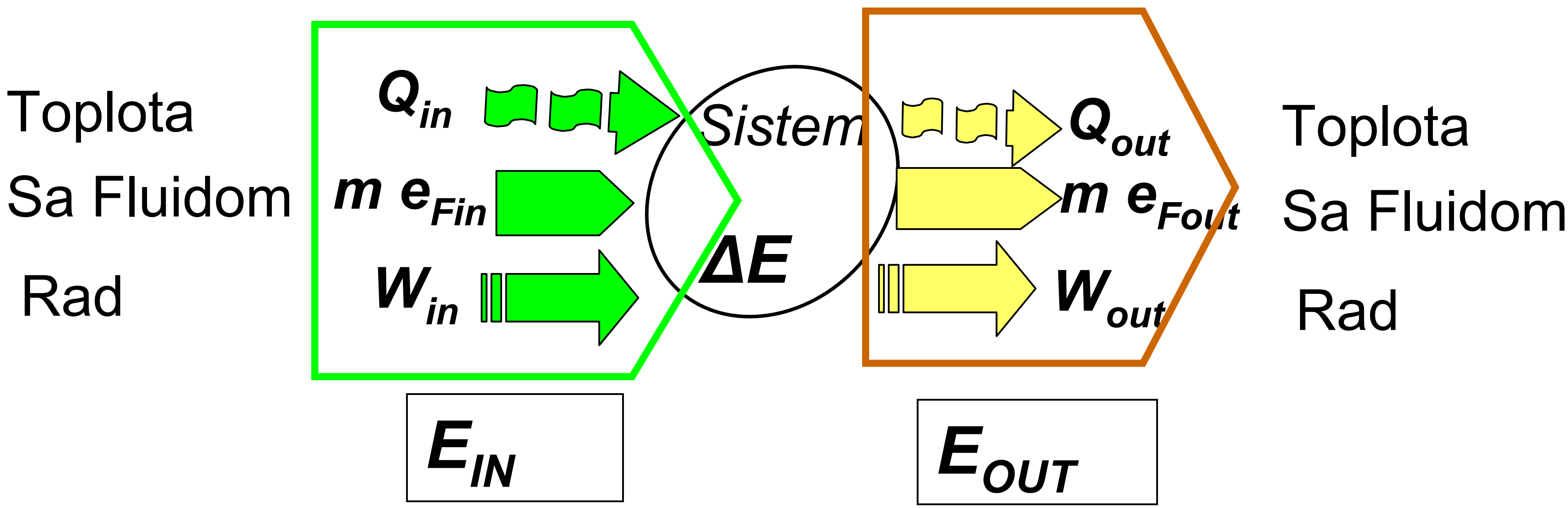
PROMJENA=ULAZ - IZLAZ



$$\Delta E = E_{in} - E_{out}$$

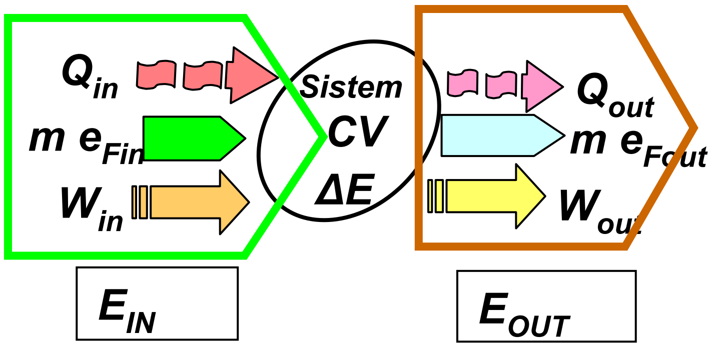
I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

- U kom obliku energija ulazi-izlazi iz posmatranog sistema?



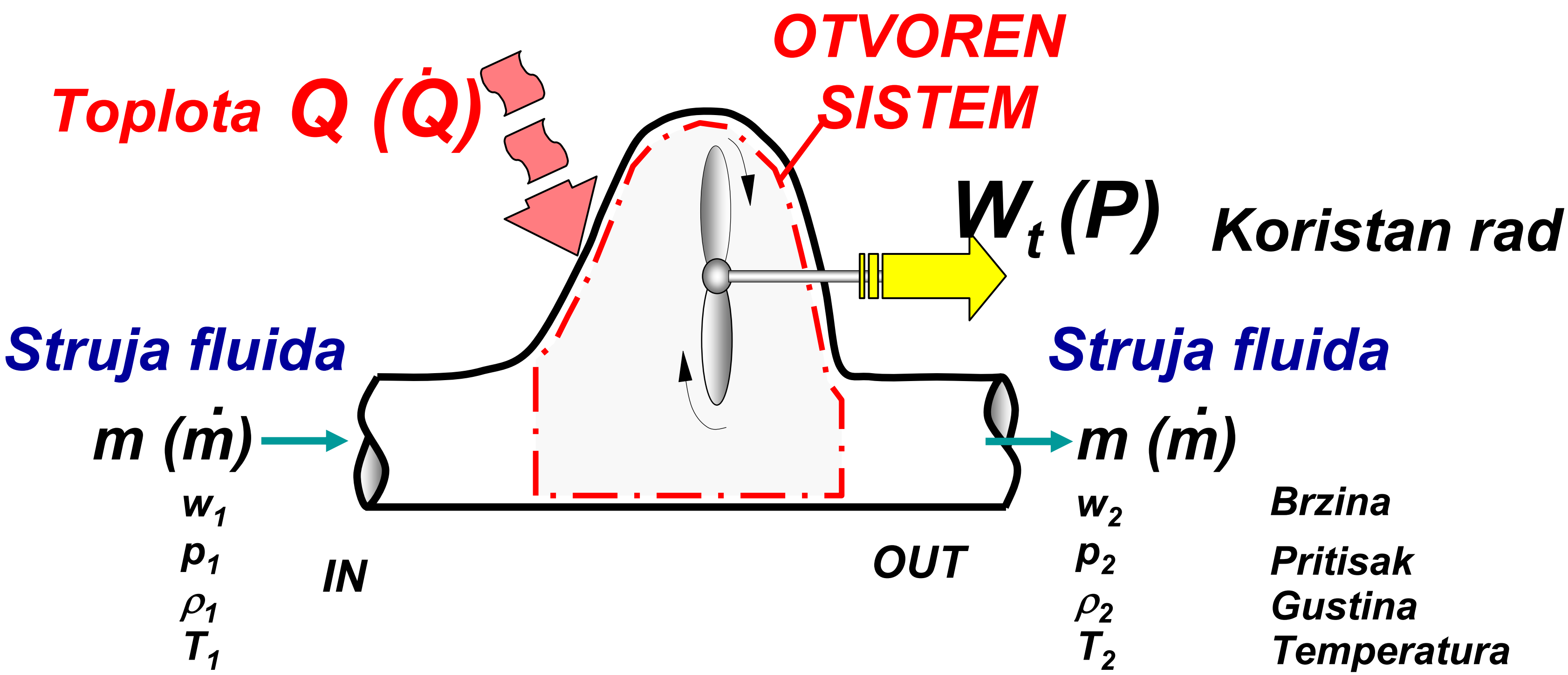
$$\Delta E=[(me_F)_{in} - (m\ e_F)]_{out} + (Q_{in} - Q_{out}) + (W_{in} - W_{out})$$

I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM



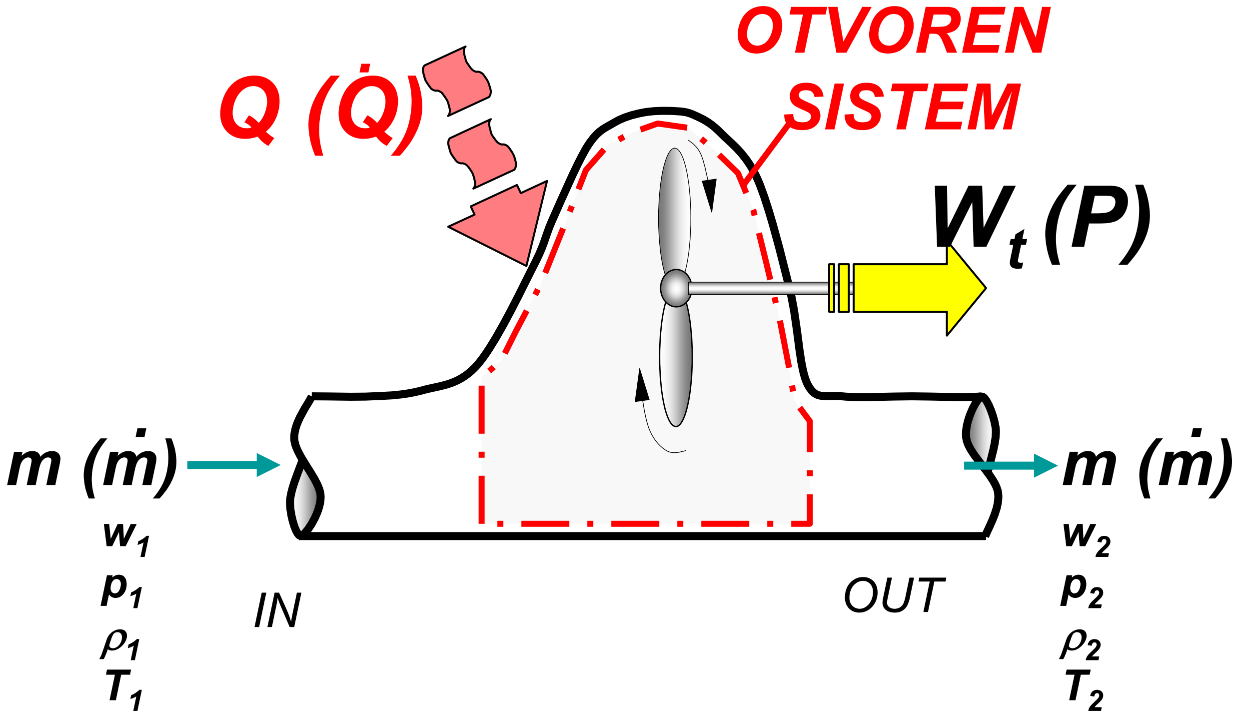
"ENERGIJA FLUIDA"

$$e_F\,[J/kg] = \left(i + \frac{w^2}{2} + gz\right)$$



I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

STACIONARAN SLUČAJ (***ΔE=0***, *Ulaz=Izlaz*)



$$\dot{Q} + \dot{m}_{in}\left(i + \frac{w^2}{2} + gz\right)_{in} = \dot{m}_{out}\left(i + \frac{w^2}{2} + gz\right)_{out} + P \quad [W, kW]$$

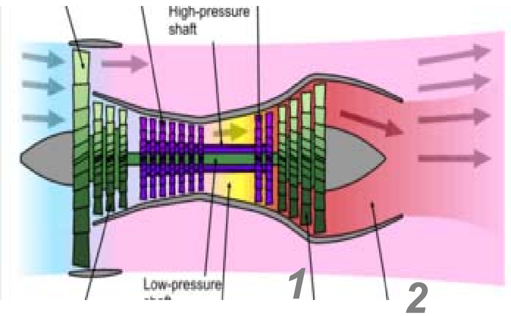
IN OUT

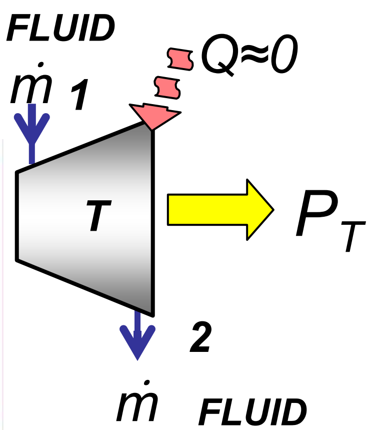
I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

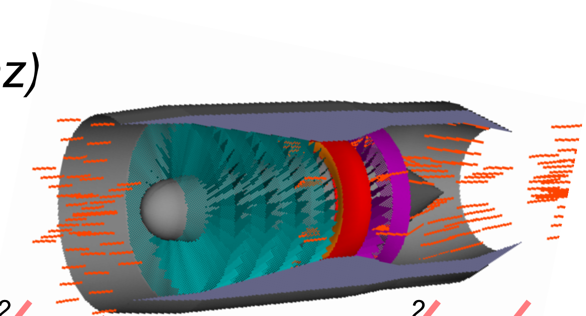
Primjeri

STACIONARAN SLUČAJ *(Ulaz=Izlaz)*

Turbina

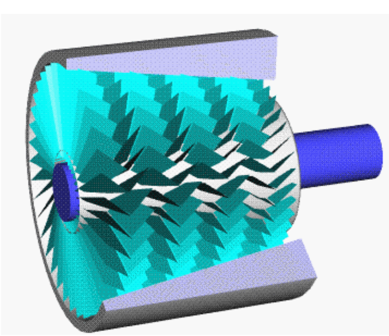


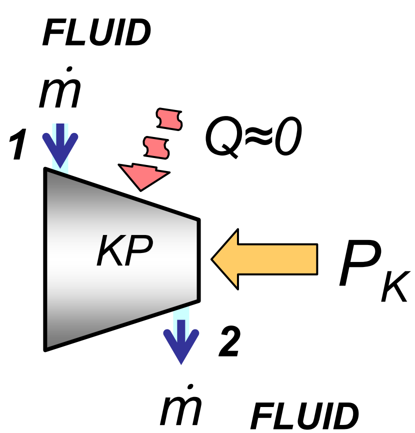




$$\cancel{\dot{Q}} + \dot{m}\left(i + \cancel{\frac{w^2}{2}} + \cancel{gz}\right)_1 = P_T + \dot{m}\left(i + \cancel{\frac{w^2}{2}} + \cancel{gz}\right)_2$$

Kompresor





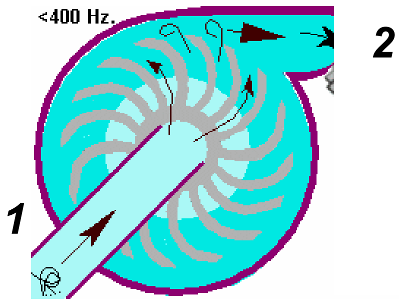
$$\cancel{\dot{Q}} + \dot{m}\left(i + \cancel{\frac{w^2}{2}} + \cancel{gz}\right)_1 + P_{KP} = \dot{m}\left(i + \cancel{\frac{w^2}{2}} + \cancel{gz}\right)_2$$

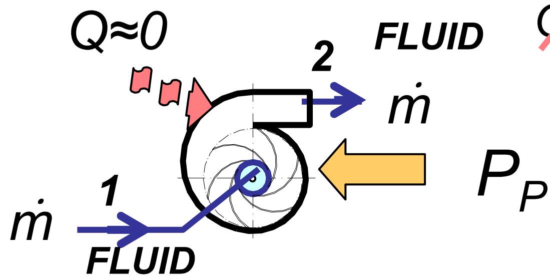
I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

STACIONARAN SLUČAJ *(Ulaz=Izlaz)*

Primjeri

Pumpa



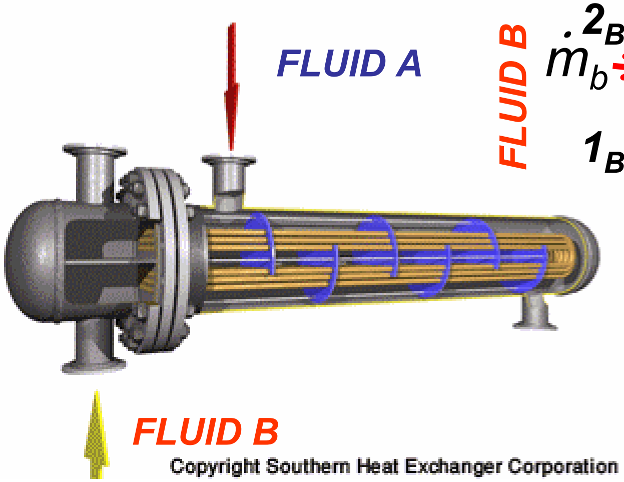


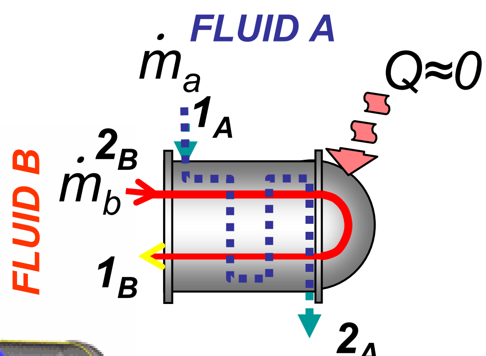
$$\cancel{\dot{Q}} + \dot{m}(i + \cancel{\frac{w^2}{2}} + \cancel{gz})_1 + P_P = \dot{m}(i + \cancel{\frac{w^2}{2}} + \cancel{gz})_2$$

$$\dot{m}(u + \frac{p}{\rho})_1 + P_P \approx \dot{m}(u + \frac{p}{\rho})_2$$

$$\dot{m}(\frac{p}{\rho})_1 + P_P \approx \dot{m}(\frac{p}{\rho})_2 + \boxed{\dot{m}(u_2 - u_1)}_{\text{TRENJE}}$$

Razmjenjivač toplote





$$\cancel{\dot{Q}} + \dot{m}_a(i + \cancel{\frac{w^2}{2}} + \cancel{gz})_{1A} + \dot{m}_b(i + \cancel{\frac{w^2}{2}} + \cancel{gz})_{1B} =$$

$$= \cancel{P} + \dot{m}_a(i + \cancel{\frac{w^2}{2}} + \cancel{gz})_{2A} + \dot{m}_b(i + \cancel{\frac{w^2}{2}} + \cancel{gz})_{2B}$$

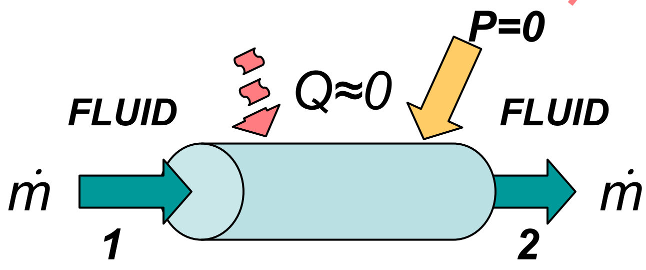
I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

Primjeri

***STACIONARAN SLUČAJ** (Ulaz=Izlaz)*

Strujanje kroz cijevi-kanale

$$\dot{Q} + \dot{m}\left(i + \frac{w^2}{2} + gz\right)_1 + P = \dot{m}\left(i + \frac{w^2}{2} + gz\right)_2$$



$$\left(i + \frac{w^2}{2} + gz\right)_1 = \left(i + \frac{w^2}{2} + gz\right)_2$$

$$i = u + \frac{p}{\rho}$$

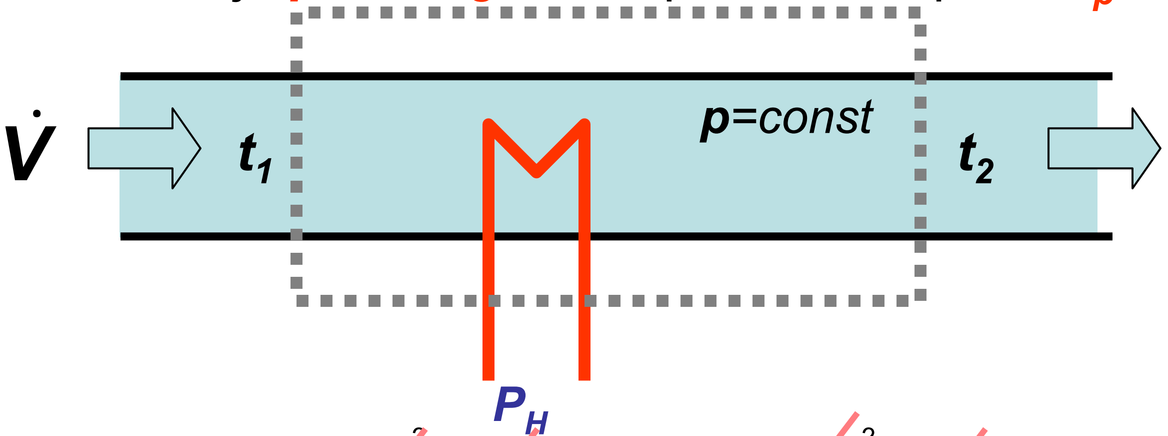
$$\left(\frac{p}{\rho} + \frac{w^2}{2} + gz\right)_1 = \left(\frac{p}{\rho} + \frac{w^2}{2} + gz\right)_2 + \left(u_2 - u_1\right)\Big|_{TRENJE}$$

$$\left(u_2 - u_1\right)\Big|_{TRENJE} = \frac{\Delta p}{\rho}\Big|_{TRENJE}$$

$$\left(\mathbf{p} + \rho\frac{w^2}{2} + \rho gz\right)_1 = \left(\mathbf{p} + \rho\frac{w^2}{2} + \rho gz\right)_2 + \Delta\mathbf{p}\Big|_{TRENJE}$$

Primjer

Kolika je snaga (P_G) kanalskog grijača koji treba da grije *1000 m^3/h* vazduha od t_1=5 C do t_2=20 C.
Gustina vazduha je ρ=1.2 kg/m^3 a specifična toplota c_p=1 kJ/kgK.



$$\dot{Q} + \dot{m}\left(i + \frac{w^2}{2} + gz\right)_1 + P = \dot{m}\left(i + \frac{w^2}{2} + gz\right)_2$$

$$\dot{Q}, P_H[W, kW] = \dot{m}\,\Delta i = \dot{m}\,c_p\,\Delta t = \rho\,\dot{V}\,c_p(t_2 - t_1)$$

P_{el}=1.2*1000 / 3600*1*(20-5)=5 kW

I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

STACIONARAN SLUČAJ

(Ulaz=Izlaz)

Primjeri

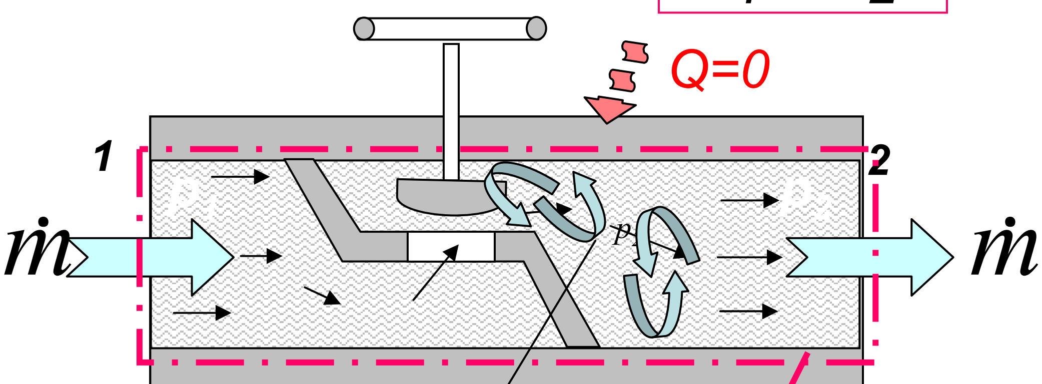
Prigušivanje

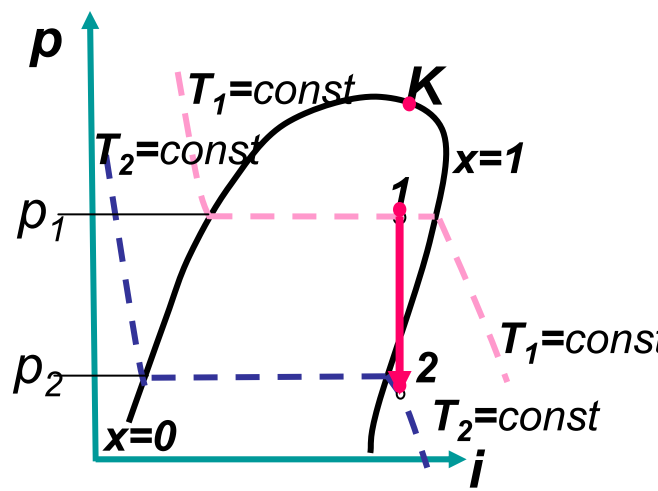
Prigušivanje se manifestuje kao pad pritiska pri strujanju fluida kroz mjesto sa lokalnim otporom.

ULAZ=IZLAZ

$$\dot{Q} + \dot{m}[i+w^2/2+gz)]_{in} = P + \dot{m}[(i+w^2/2+gZ)]_{out}$$

$$i_1 = i_2$$





I ZAKON TERMODINAMIKE ZA OTVOREN SISTEM

Primjeri

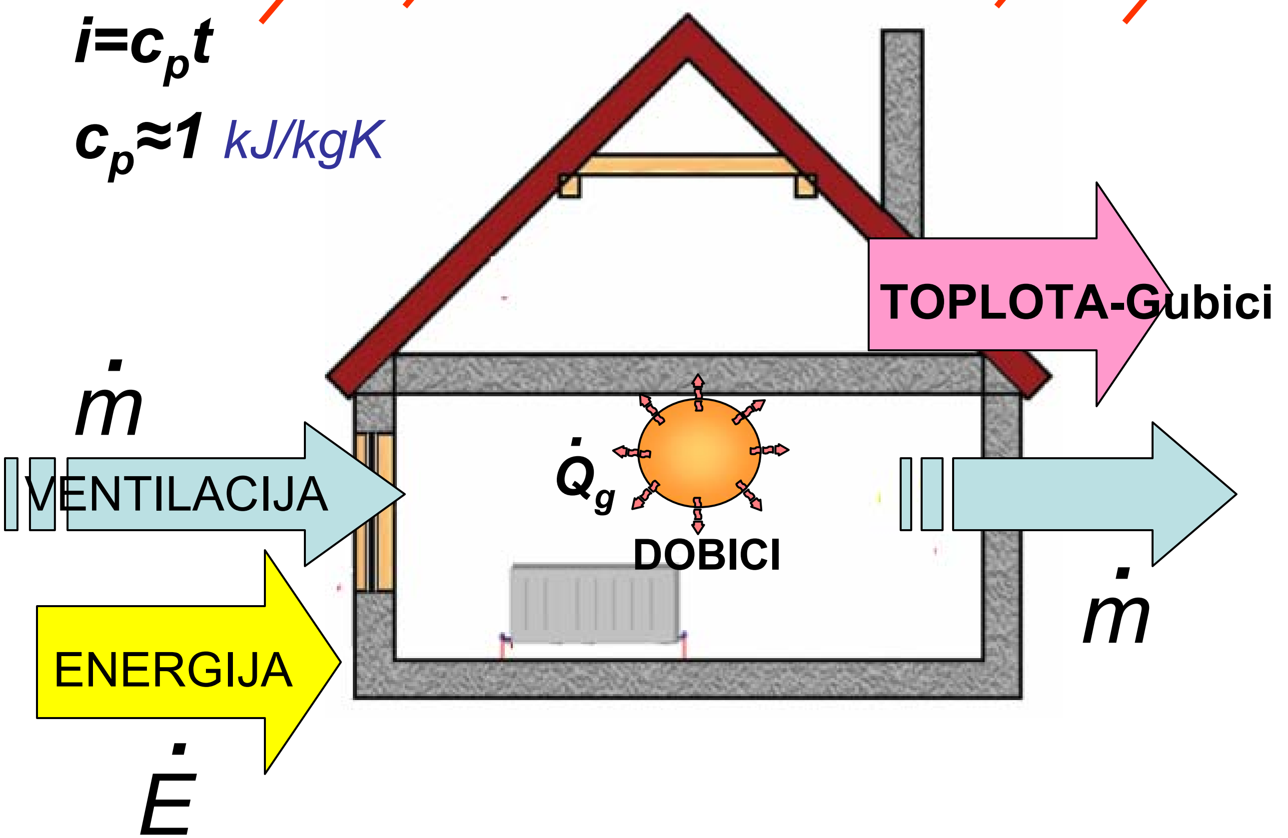
STACIONARAN SLUČAJ

(Ulaz=Izlaz)

$$\dot{E} + \dot{m}\left(i + \frac{w^2}{2} + gz\right)_{ul} + \dot{Q}_g = \dot{Q} + \dot{m}\left(i + \frac{w^2}{2} + gz\right)_{iz}$$

$i = c_p t$

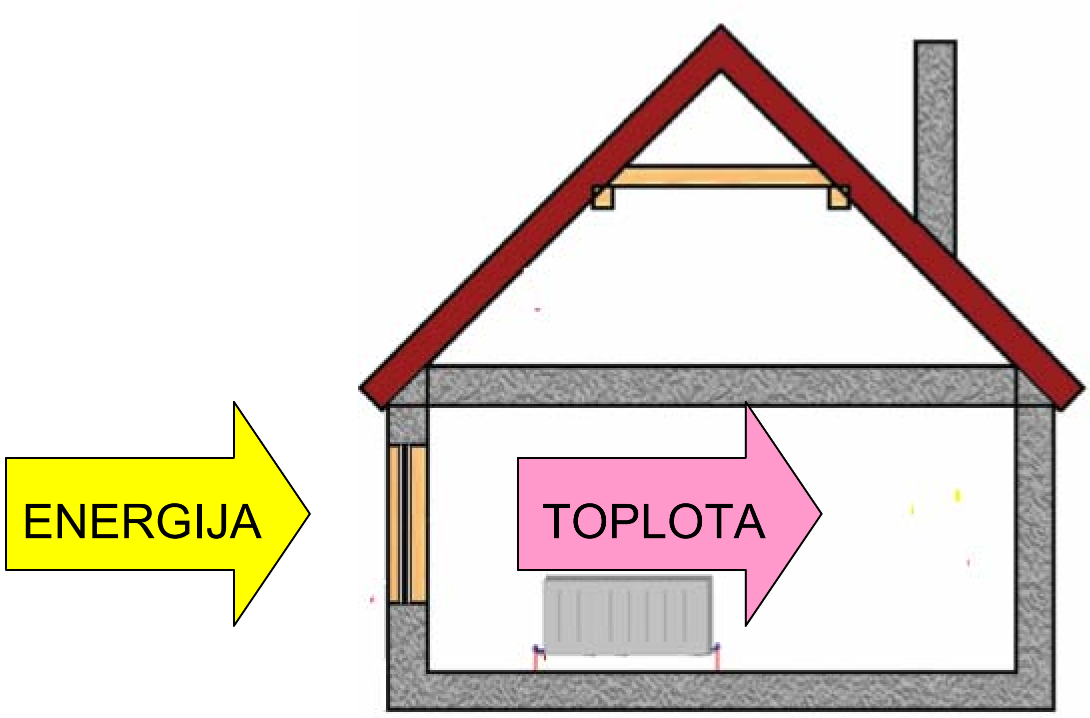
$c_p \approx 1$ kJ/kgK



I ZAKON TERMODINAMIKE U ZGRADI

Zgrada

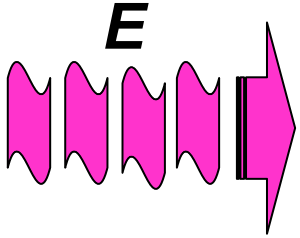
Svi oblici energije završe kao toplota.



ZGRADA SE JAVLJA KAO "TRANSFORMATOR" KOJI SVU ENERGIJU PRETVARA U TOPLOTU

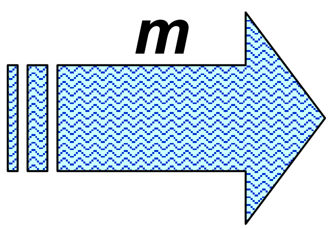
TRANSPORTNI PROCESI

E



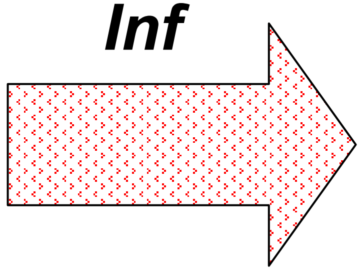
PROSTIRANJE ENERGIJE

m



PROSTIRANJE MATERIJE

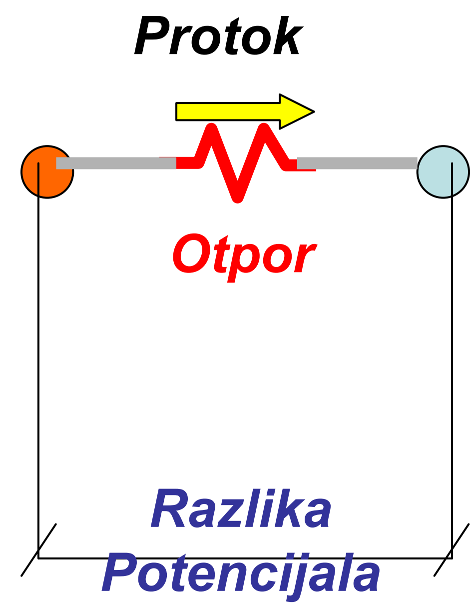
Inf



PRENOS INFORMACIJA

PROSTIRANJE TOPLOTE

POKRETAČKA SILA: **RAZLIKA POTENCIJALA**
KOČNICA: **OTPOR**
STACIONARAN SLUČAJ: **NEMA AKUMULACIJE**
SMJER: **OD VEĆEG KA MANJEM POTENCIJALU**



GENERALIZOVANI OMOV ZAKON:

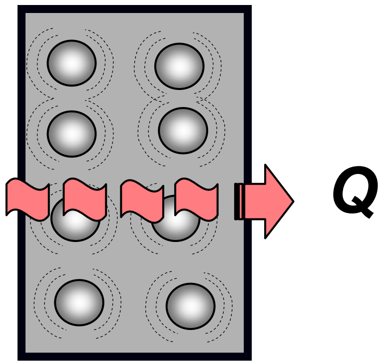
$$\text{PROTOK} \sim \frac{\text{RAZLIKA POTENCIJALA}}{\text{OTPOR}}$$

PROSTIRANJE TOPLOTE

Postoje 3 ***Mehanizma*** prostiranja toplote:

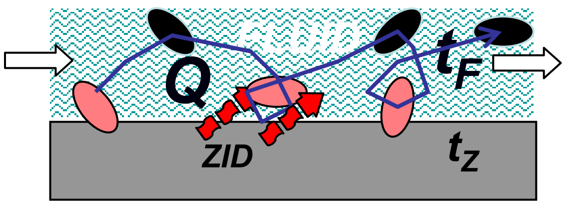
- **Kondukcija** (provodjenje toplote)

Mehanizam provodjenje toplote kontrolisan kretanjem molekula.



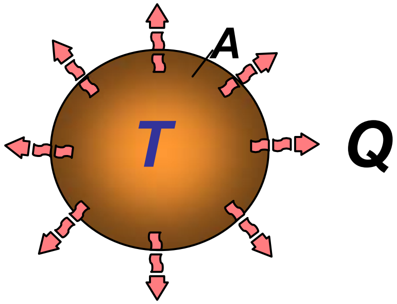
- **Konvekcija (**prelaz toplote)

Mehanizam provodjenje toplote kontrolisan kretanjem fluidnih djelića.

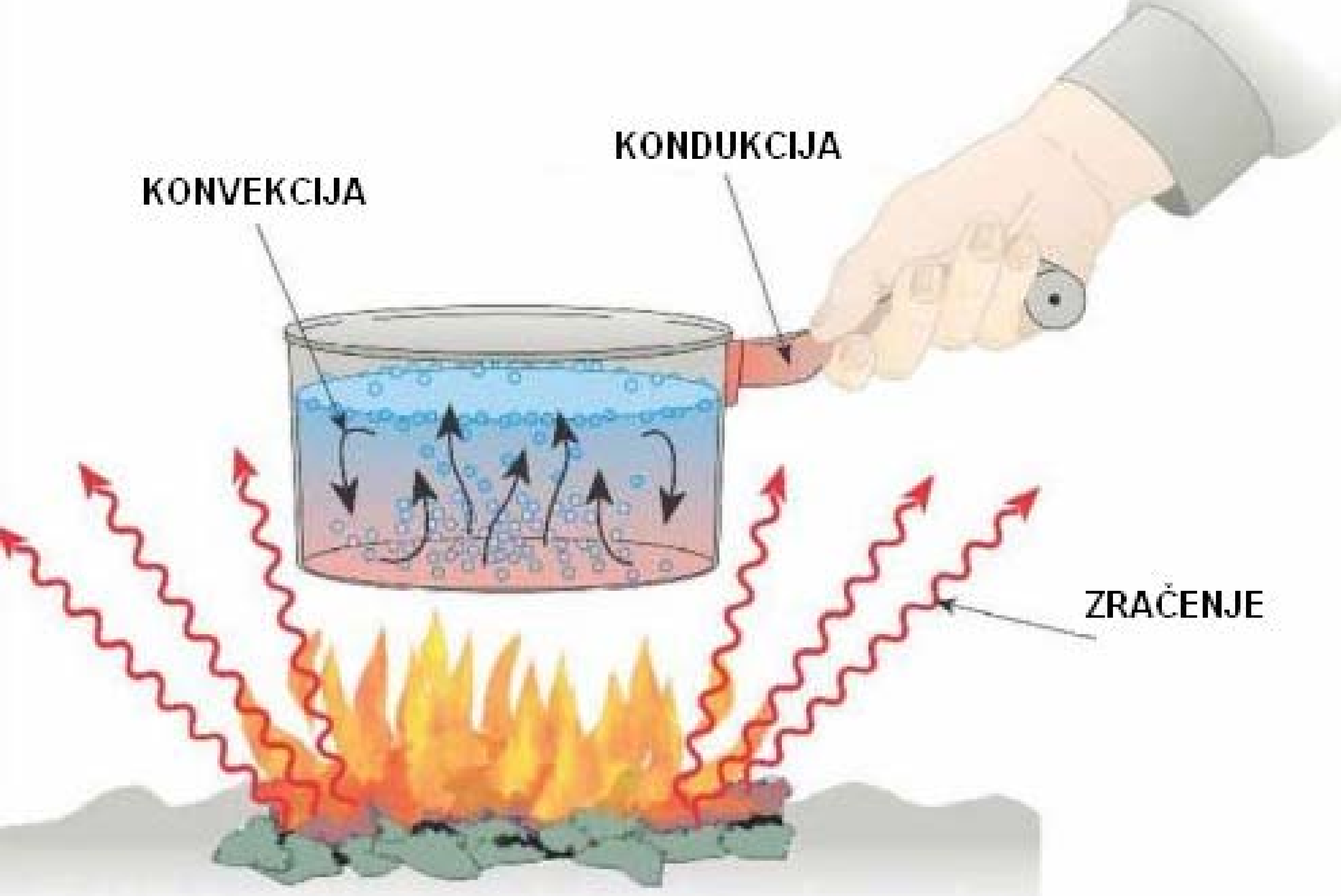


- **Radijacija** (zračenje)

Mehanizam provodjenje toplote kontrolisan zakonima elektromagnetnog zračenja.



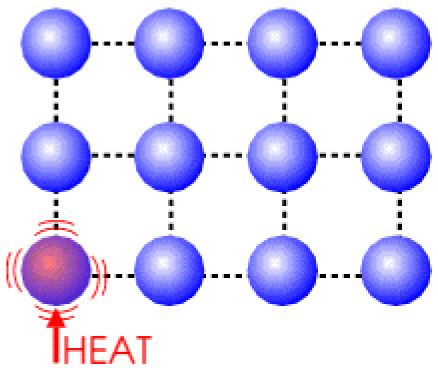
PROSTIRANJE TOPLOTE

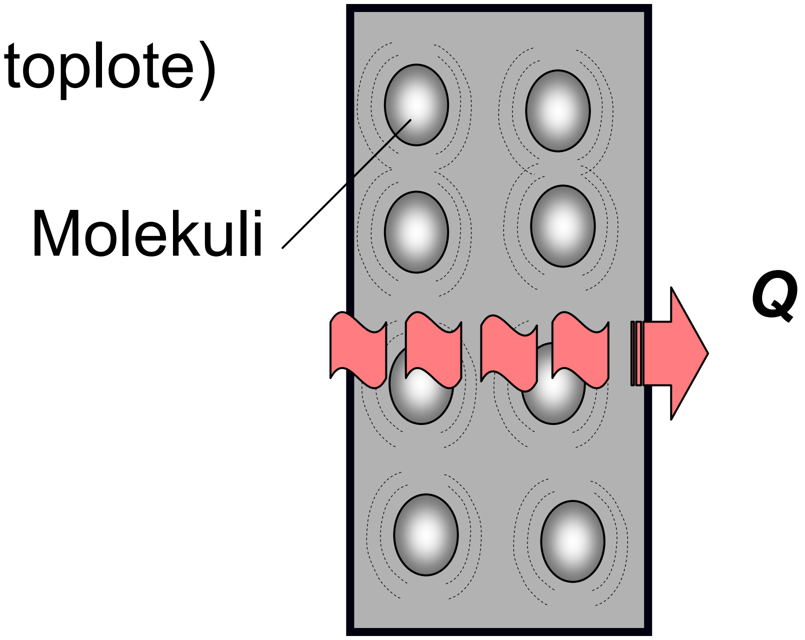


PROSTIRANJE TOPLOTE

Postoje 3 ***Mehanizma*** prostiranja toplote:

•**Kondukcija** (provodjenje toplote)

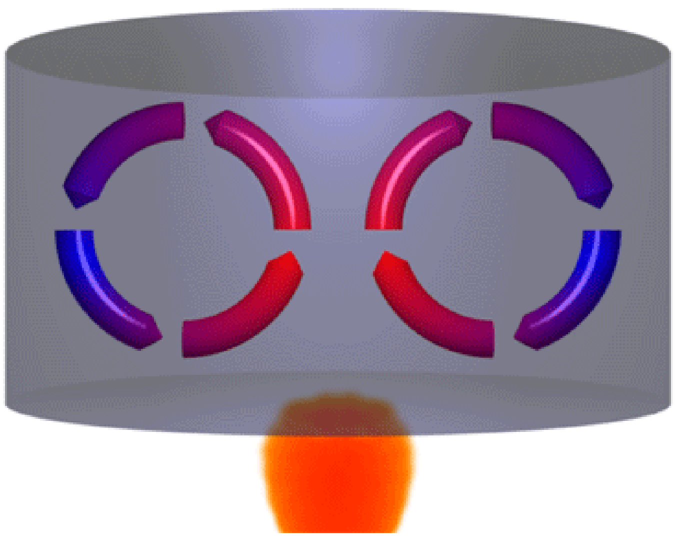


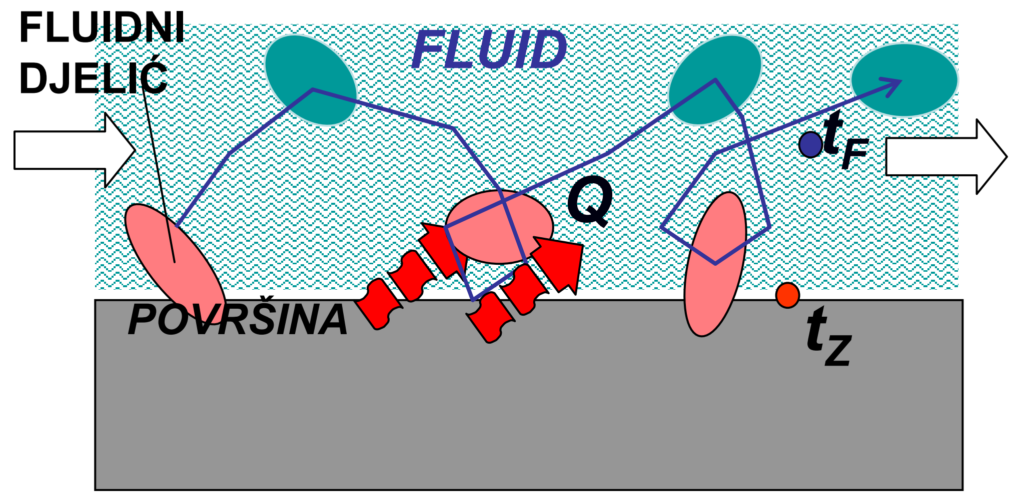


Toplota se prenosi vibriranjrm molekula u tijelu. Ovaj vid prostiranja toplote je dominantan u čvrstim tijelima.

PROSTIRANJE TOPLOTE

•**Konvekcija (**prelaz toplote)



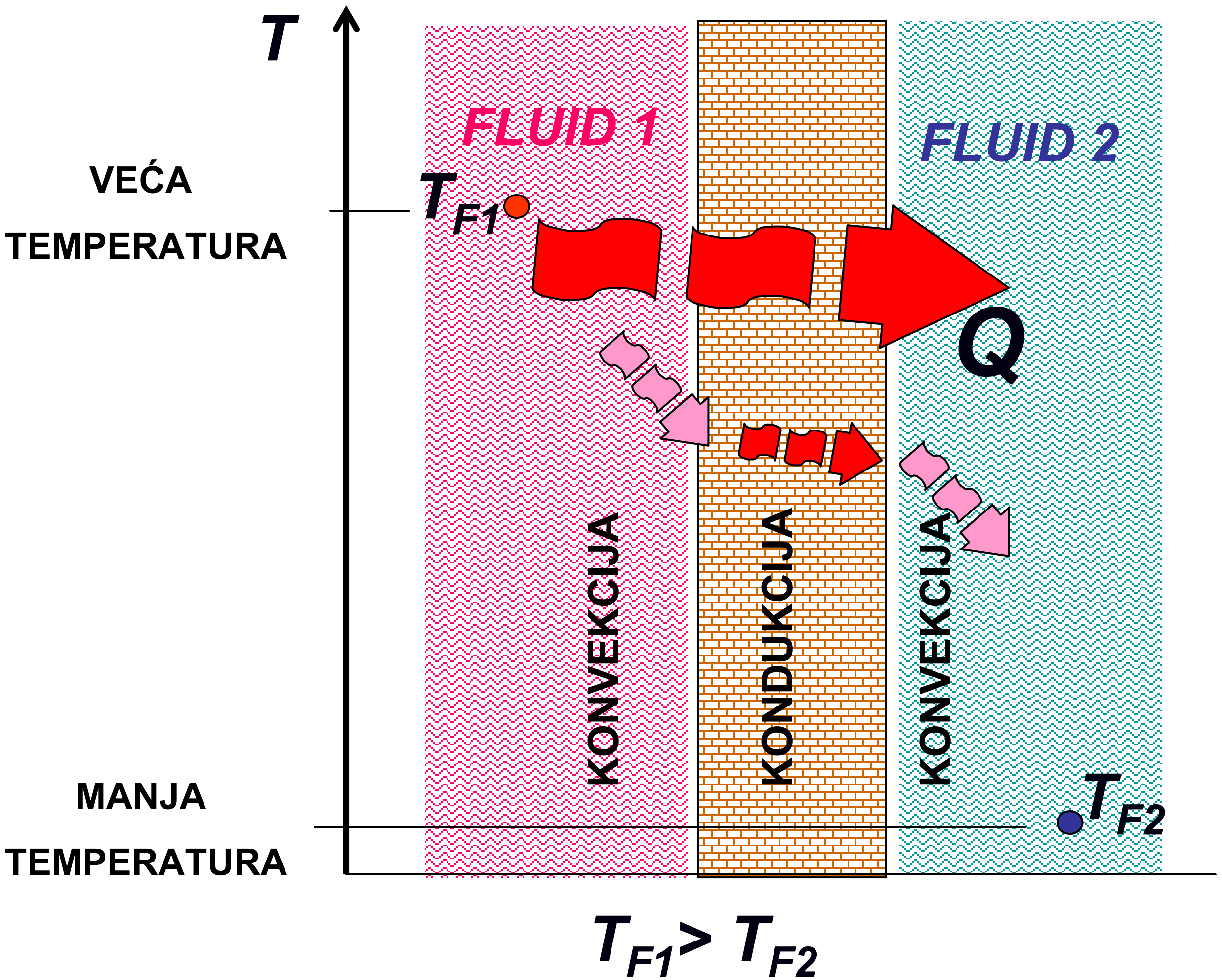


Toplota prelazi sa neke površine na fluid i obratno. Fluidni djelići dolaze do površine, razmijene sa njom energiju i odu nazad u struju. Što je intezivnije kretanje fluida razmjena toplote je jača.

Konvekcija se javlja i na površini koja dijeli tečnost i vazduh.

PROSTIRANJE TOPLOTE

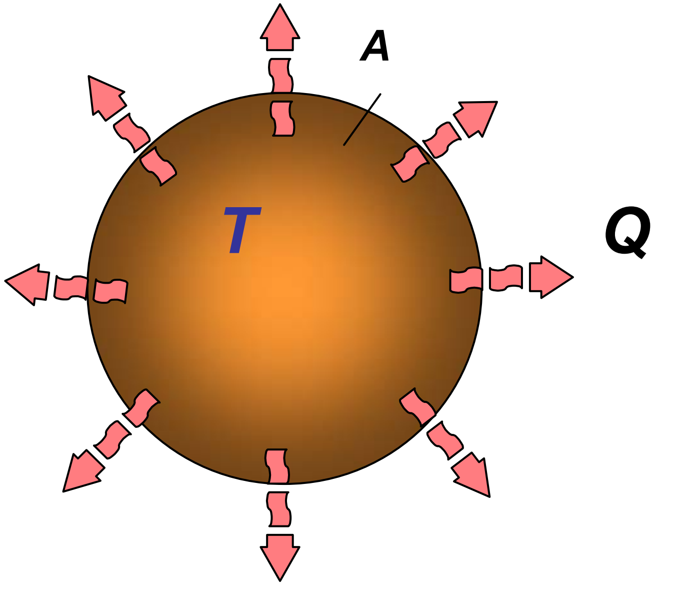
- PROLAZ TOPLOTE = Konvekcija + Kondukcija



PROSTIRANJE TOPLOTE

•**Radijacija** (zračenje)

Svako tijelo zagrijano iznad apsolutne nule zrači.



Za razliku od prethodnih slučajeva, toplota se zračenjem prostire i u vakuumu (kao svjetlost ili radiotalasi).

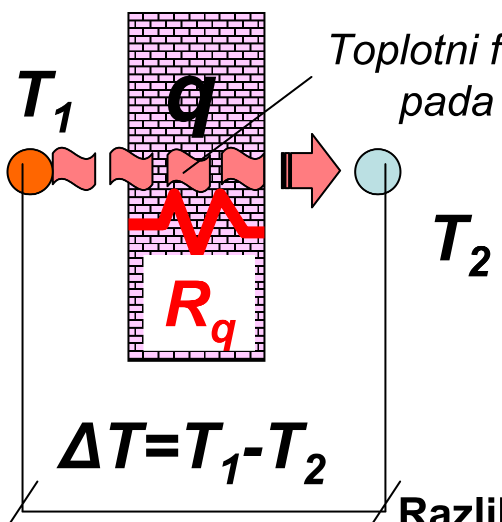
PROSTIRANJE TOPLOTE

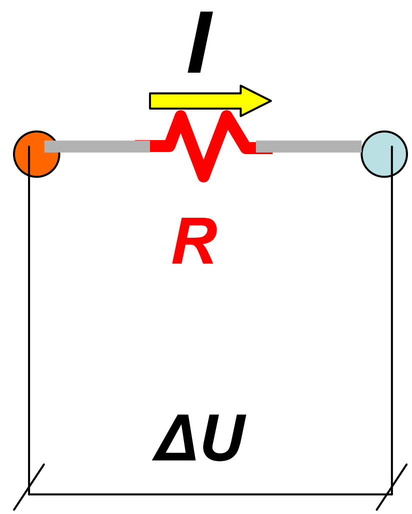
Električna analogija

q *[W/m²] – gustina toplotnog fluksa (protoka),* $\dot{Q}[W]=q*A$

Prostiranje toplote | Električna struja

Toplotni fluks, je u smjeru pada temperature





Razlika potencijala

$$q = \frac{\Delta T}{R_q}$$

Toplotni otpor

$$I = \frac{\Delta U}{R}$$

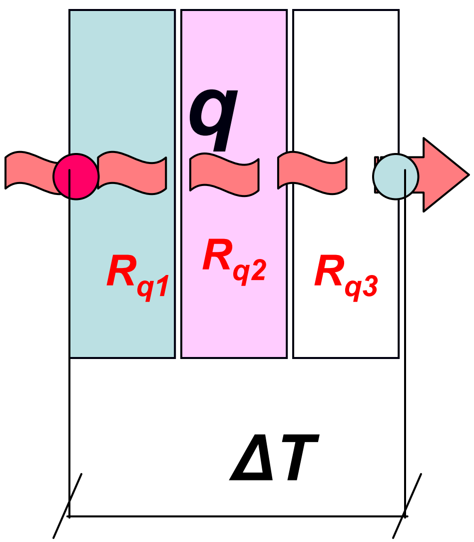
SMJER ***q***: OD VEĆE (T_1) KA MANJOJ (T_2) TEMPERATURI

PROSTIRANJE TOPLOTE

Električna analogija – redno vezani otpori

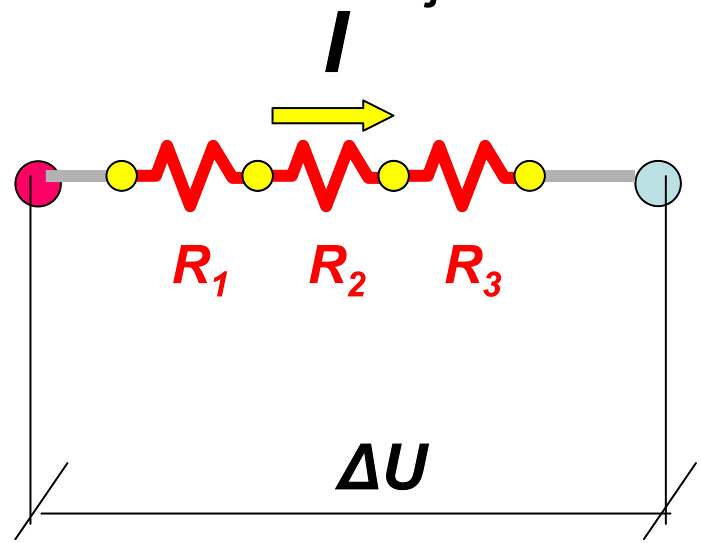
U STACIONARNOM SLUČAJU PROTOK JE ISTI KROZ SVE OTPORE

Prostiranje toplote



$$q = \frac{\Delta T}{R_{q1} + R_{q2} + R_{q3}}$$

Električna struja



$$I = \frac{\Delta U}{R_1 + R_2 + R_3}$$

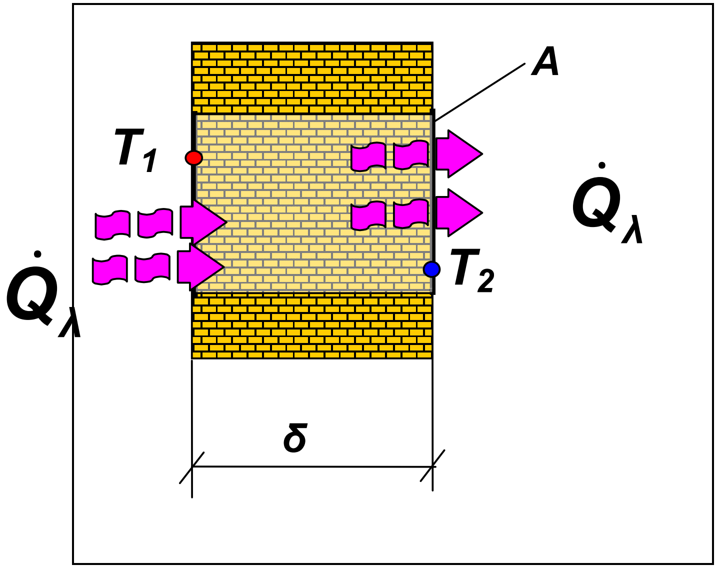
SMJER ***q***: OD VEĆE KA MANJOJ TEMPERATURI

PROSTIRANJE TOPLOTE

Kondukcija – provodjenje toplote

$\dot{Q}_\lambda$ [W]= Aq_λ – Toplotni fluks

q [W/m^2] – Gustina topl. fluksa



ΔT [K]=T_1-T_2 – Razlika temperatura

A [m^2] - Površina razmjene

δ [m] – Debljina zida

λ [W/mK] – Koeficijent provodjenja toplote

$$R_\lambda = \frac{\delta}{\lambda}$$

$$q_\lambda = \frac{\Delta T}{R_\lambda} = \frac{T_1 - T_2}{\frac{\delta}{\lambda}}$$

$$\dot{Q}_\lambda = Aq$$

SMJER q: OD VEĆE (T_1) KA MANJOJ (T_2) TEMPERATURI

PROSTIRANJE TOPLOTE

Provodjenje toplote (Kondukcija)

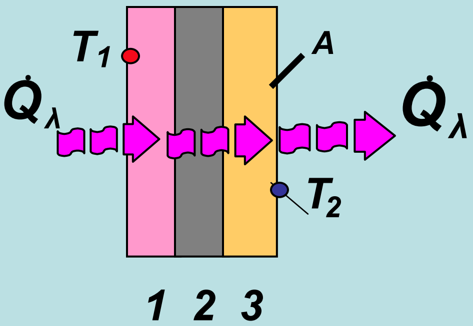
λ [W/mK] - Koeficijenat provodjenja toplote je karakteristika materijala. Dobar električni provodnik obično ima i veliko ***λ.***

Materijal	*λ [W/mK]*
Kamen, Beton, Opeka, Staklo	*~ 1*
Metal	*~ 50 - 200*
Drvo	*~ 0.1*
Voda	*~ 0.6*
Vazduh	*~ 0.02*
Izolacija (toplotna)	*~ 0.04*

PROSTIRANJE TOPLOTE

Kondukcija-provođenje toplote – Višeslojan zid

KROZ SVAKI SLOJ PROLAZI ISTI TOPL. FLUKS



$$q_\lambda = \frac{\Delta T}{R_\lambda} = \frac{\Delta T}{R_{\lambda 1} + R_{\lambda 2} + R_{\lambda 3}} \, [W/m^2]$$

$$\Delta T = T_1 - T_2$$

$$R_{\lambda 1} = \left(\frac{\delta}{\lambda}\right)_1 \quad R_{\lambda 2} = \left(\frac{\delta}{\lambda}\right)_2 \quad R_{\lambda 3} = \left(\frac{\delta}{\lambda}\right)_3$$

$$\dot{Q}_\lambda \left[W\right] = A q_\lambda = A \frac{t_1 - t_2}{R_\lambda} = A \frac{t_1 - t_2}{\sum \frac{\delta}{\lambda}}$$

SMJER Q_λ, q_λ : OD VEĆE (T_1) KA MANJOJ (T_2) TEMPERATURI

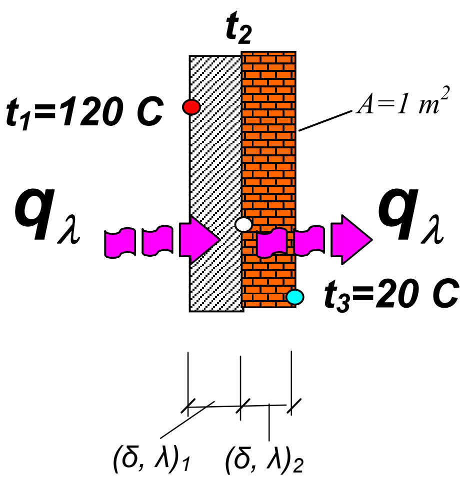
PROSTIRANJE TOPLOTE

Kondukcija-provođenje toplote – Višeslojan zid

Primjer.

Zid ima dva sloja.

Podaci: $\delta_1=0.1$ m, $\lambda_1=0.1$ W/mK
$\delta_2=0.25$ m, $\lambda_2=1.5$ W/mK
(uzimamo $A=1\ m^2$)

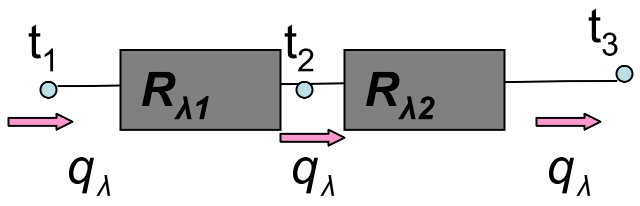


$R_{\lambda 1}=(\delta/\lambda)_1= 0.1/ 0.1= 1$

$R_{\lambda 2}= (\delta/\lambda)_2=0.25/ 1.5 = 0.17$

$R_{\lambda}= R_{\lambda 1}+R_{\lambda 2}=1+0.17 = 1.17$

$\Delta t= t_1-t_3= 120-20= 100,\quad q_\lambda=\frac{\Delta t}{R_q}=\frac{100}{1.17}=85.5\,W/m^2$



Toplotni fluks je isti kroz sve slojeve zida.

..<u>Odredjivanje temperature</u> t_2

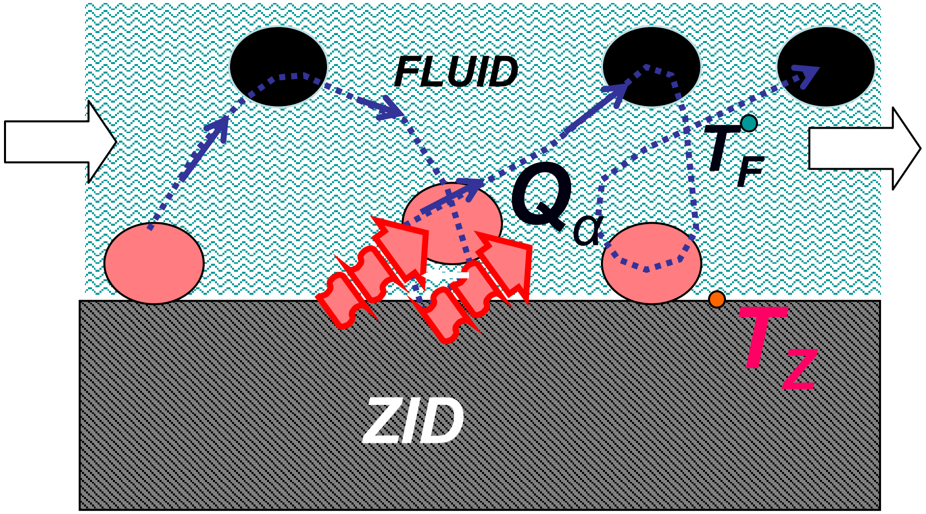
$$q_\lambda\Big|_{Sloj1}=\frac{t_1-t_2}{\left(\frac{\delta}{\lambda}\right)_1},\quad t_2=t_1-q_\lambda\left(\frac{\delta}{\lambda}\right)_1=120-85.5*1=34.5\ \mathbf{C}$$

SMJER q: OD VEĆE (T_1) KA MANJOJ (T_3) TEMPERATURI

PROSTIRANJE TOPLOTE

Konvekcija (prelaz toplote) - Ravan zid

Ovaj oblik prostiranja toplote je kontrolisan kretanjem fluidnih djelića, dakle dominantno zavisi od brzinskog polja.



Njutnova formula:

$$q_\alpha \,[W/m^2] = \alpha \, \Delta T$$

$$\dot{Q}_\alpha \,[W] = A \, q_\alpha$$

SMJER $\boldsymbol{q_\alpha}$: OD VEĆE (T_Z) KA MANJOJ (T_F) TEMPERATURI

$A\,[m^2]$ **- Površina**

$\alpha\,[W/m^2K]$ **- Koeficijenat prelaza toplote**

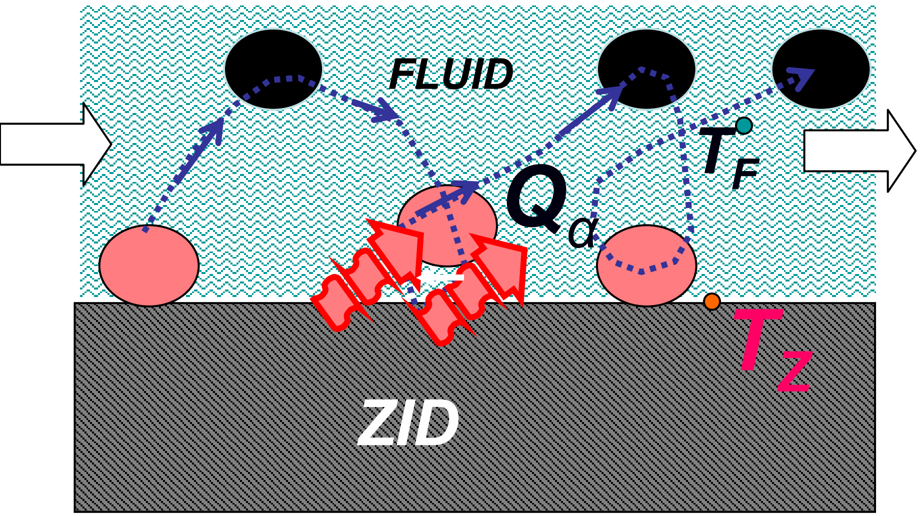
$\Delta T\,[K] = T_z - T_F$ **- Razlika temperatura**

PROSTIRANJE TOPLOTE

Konvekcija (prelaz toplote)- Ravan zid

Toplotni otpor konvekcije R_α

$$q_\alpha\,[W/m^2] = \alpha\,\Delta T$$



$$q_\alpha = \frac{\Delta T}{\frac{1}{\alpha}} = \frac{\Delta T}{R_\alpha}$$

$$R_\alpha = \frac{1}{\alpha}$$

SMJER q_α: OD VEĆE (T_Z) KA MANJOJ (T_F) TEMPERATURI

$q_\alpha[W/m^2]$ – **Gustina toplotnog fluksa (protoka)**

$A\,[m^2]$ - **Površina**

$\alpha\,[W/m^2K]$ - **Koeficijenat prelaza toplote**

$\Delta T\,[K]=T_z-T_F$ - **Razlika temperatura**

$$\dot{Q}_\alpha\,[W] = A q_\alpha$$

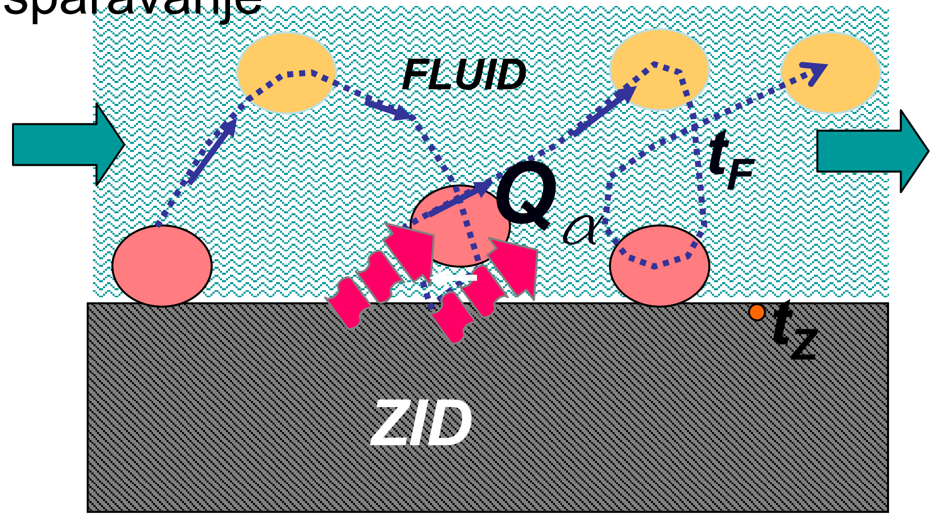
PROSTIRANJE TOPLOTE

Konvekcija *(prelaz toplote)*

α *[W/m²K]* ***- Koeficijenat Prelaza Toplote (KPT)***

- Orjentacione vrijednosti ***KPT*** $\alpha\ [\frac{W}{m^2K}]$

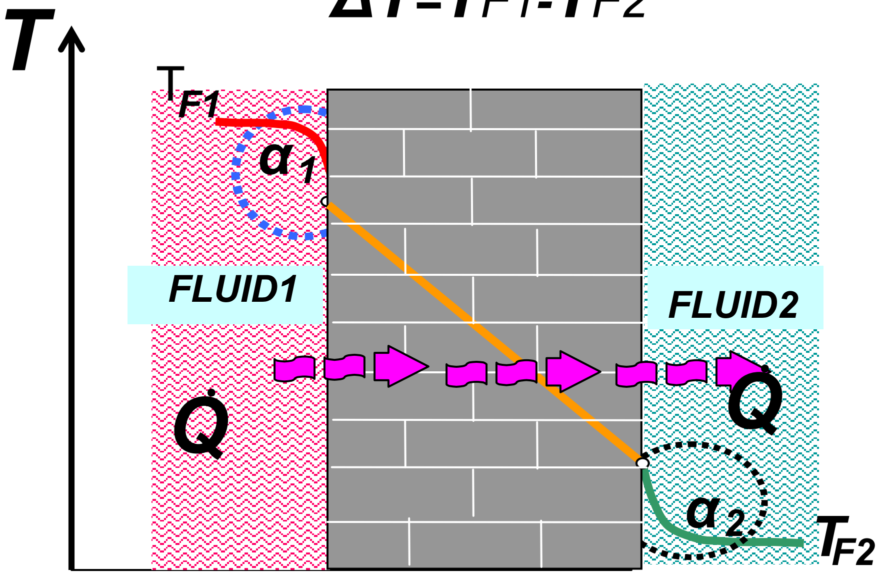
Vazduh u miru	*~ 10 (7.5)*
Strujanje gasova (vjetar itd)	*~ 20-30 (25)*
Strujanje tečnosti	*~ 1000*
Kondenzacija	*~>1000*
Isparavanje	*~ 500-1000*



PROSTIRANJE TOPLOTE

***Prolaz** toplote (Konvekcija+Kondukcija)*

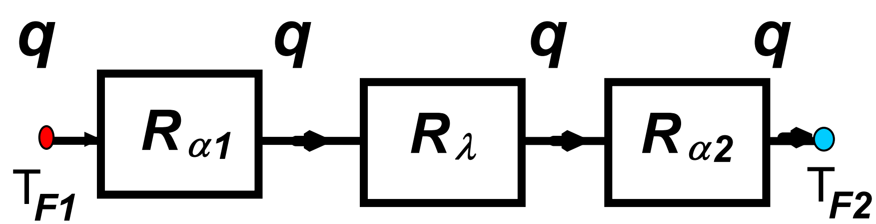
$\Delta T = T_{F1} - T_{F2}$



$$q\left[W/m^2\right] = \frac{\Delta T}{R_{\alpha 1} + R_{\lambda} + R_{\alpha 2}}$$

$$\dot{Q}\left[W\right] = Aq$$

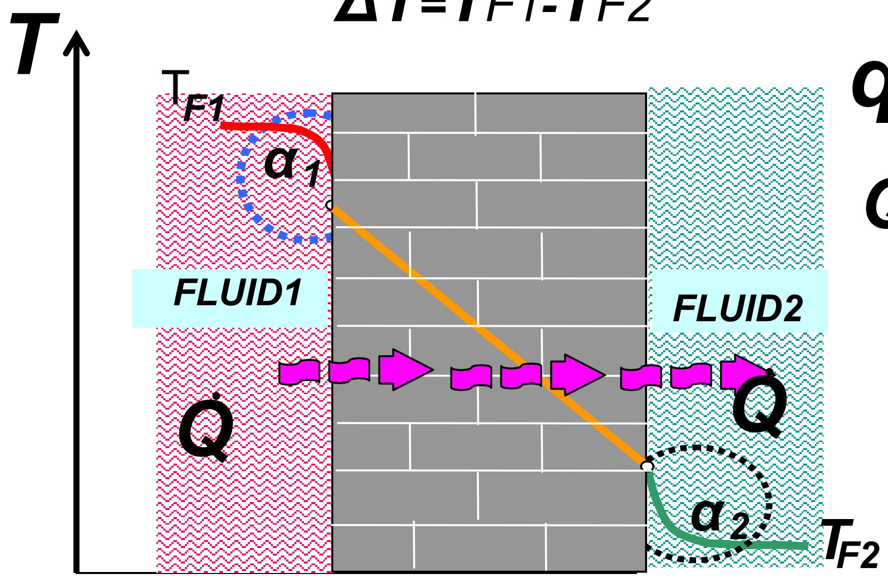
SMJER Q, q: OD VEĆE (T_{F1}) KA MANJOJ (T_{F2}) TEMPERATURI



PROSTIRANJE TOPLOTE

Koeficijenat **prolaza** toplote **U** *[W/m²K]* ili **k** *[W/m²K]*

$\Delta T = T_{F1} - T_{F2}$



q [W/m²] $= U(k)\ \Delta T$

$\dot{Q}$ [W] $= Aq$

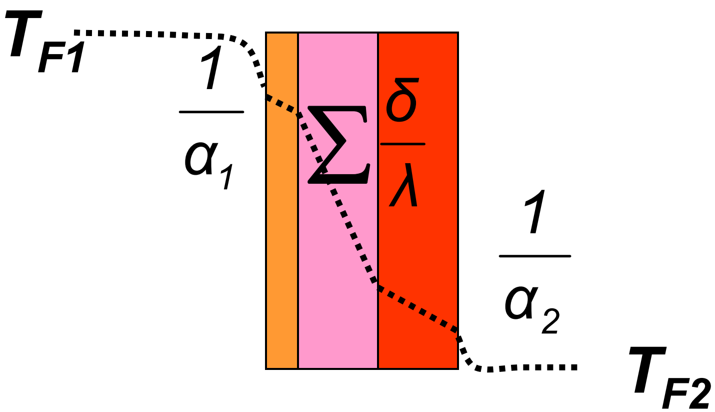
SMJER Q, q : OD VEĆE (T_{F1}) KA MANJOJ (T_{F2}) TEMPERATURI

Koeficijenat **prolaza** toplote **U** *[W/m²K]* (**k** *[W/m²K]*), predstavlja integralnu karakteristiku procesa transfera toplote izmedju 2 fluida odvojena zidom.

q *[W/m²]* predstavlja *gustinu toplotnog fluksa,* tj. toplotni fluks po *1 m²*.

PROSTIRANJE TOPLOTE

Koeficijenat **prolaza** toplote ***U*** *[W/m²K]* ili ***k*** *[W/m²K]*



$$\dot{Q}[W] = Aq$$

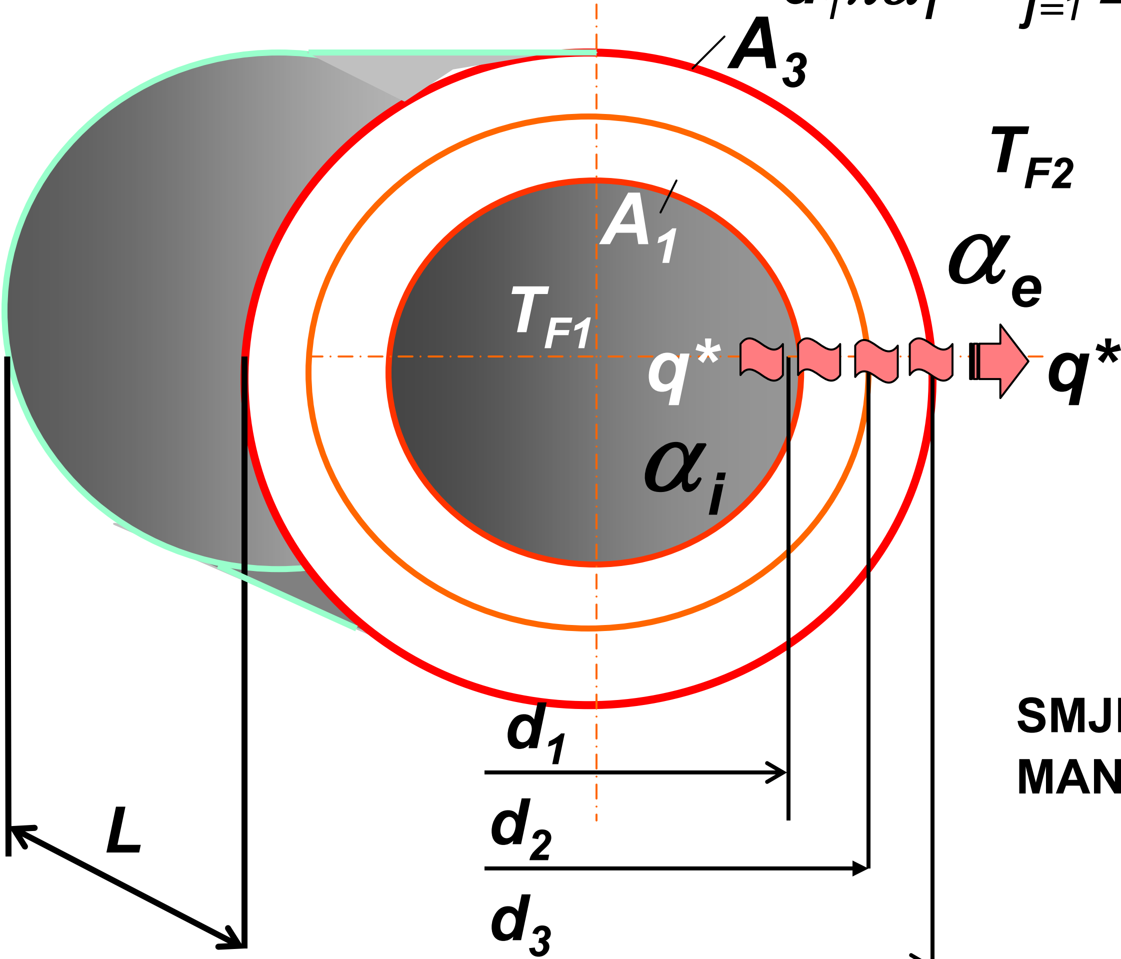
$$q = \frac{\Delta T}{R_q} = U(k)\Delta T \Rightarrow R_q = 1/U(k)$$

$$R_q = \frac{1}{\alpha_1} + \sum \frac{\delta}{\lambda} + \frac{1}{\alpha_2} = \frac{1}{U}$$

$$U\left[\frac{W}{m^2K}\right] = \frac{1}{\frac{1}{\alpha_1} + \sum \frac{\delta}{\lambda} + \frac{1}{\alpha_2}}$$

PROSTIRANJE TOPLOTE
Prolaz toplote – Cilindričan zid

$$q^*[W/m] = \frac{\Delta T}{\frac{1}{d_1 \pi \alpha_i} + \sum_{j=1}^{2} \frac{1}{2\pi\lambda_j} \ln \frac{d_{j+1}}{d_j} + \frac{1}{d_3 \pi \alpha_e}}$$

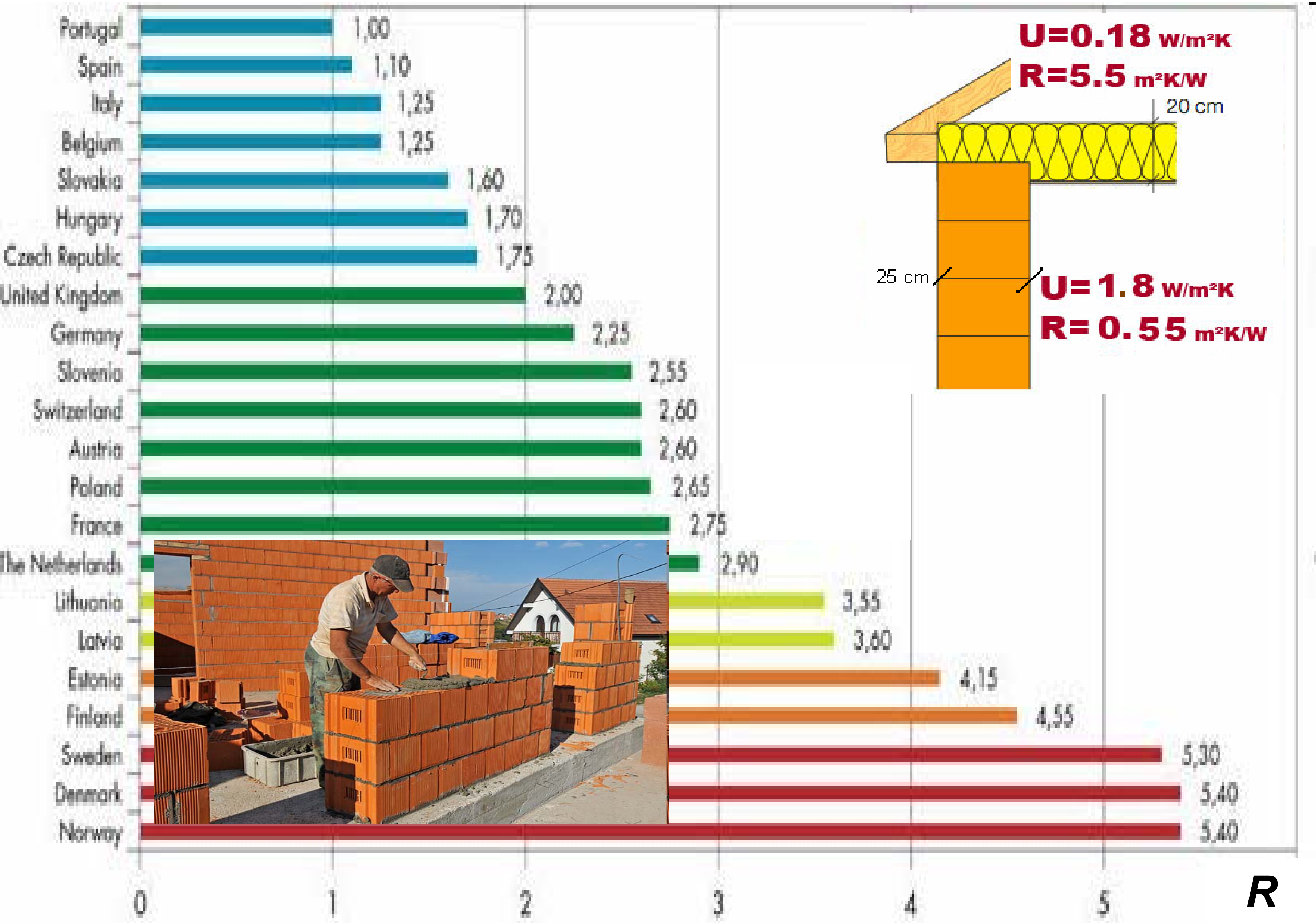


$$\dot{Q}[W] = Lq^*$$

L [m] – dužina cijevi

q[W/m] – gustina topl. fluksa (fluks po 1m dužine)*

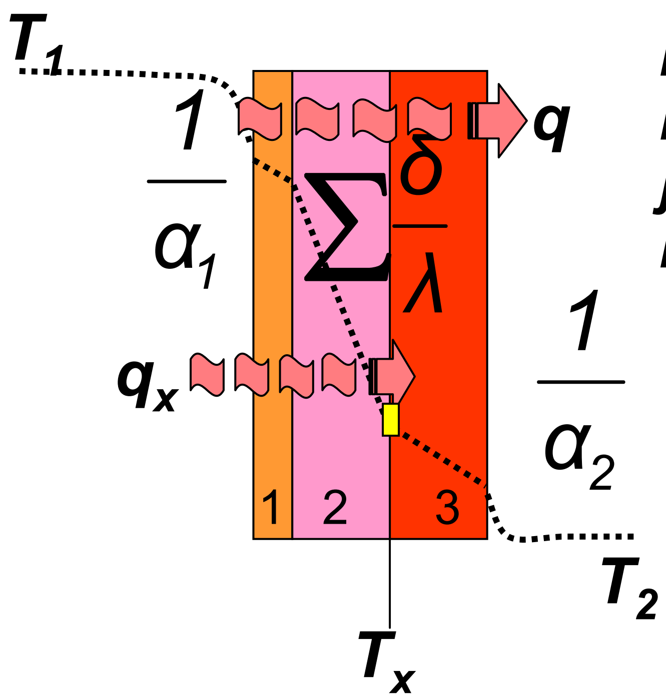
SMJER *Q, q*: OD VEĆE (T_{F1}) KA MANJOJ (T_{F2}) TEMPERATURI


Portugal 1,00
Spain 1,10
Italy 1,25
Belgium 1,25
Slovakia 1,60
Hungary 1,70
Czech Republic 1,75
United Kingdom 2,00
Germany 2,25
Slovenia 2,55
Switzerland 2,60
Austria 2,60
Poland 2,65
France 2,75
The Netherlands 2,90
Lithuania 3,55
Latvia 3,60
Estonia 4,15
Finland 4,55
Sweden 5,30
Denmark 5,40
Norway 5,40
0
1
2
3
4
5
R
U=0.18 W/m²K
R=5.5 m²K/W
20 cm
25 cm
U=1.8 W/m²K
R= 0.55 m²K/W

PROSTIRANJE TOPLOTE

Prolaz toplote:

Kako odrediti temperaturu u nekom sloju zida (T_x)?



Kroz svaki sloj zida prolazi isti fluks Q** [w]. **Prema tome fluks koji prolazi kroz zid (Q) jednak je fluksu koji koji prolazi i kroz bilo koji sloj zida ($Q=Q_x$).

Fluks kroz zid (od T_1 do T_2):

$$q = U\Delta T = \frac{\Delta T}{\frac{1}{U}} = \frac{T_1 - T_2}{\frac{1}{\alpha_1} + \sum_1^3 \frac{\delta}{\lambda} + \frac{1}{\alpha_2}}$$

Fluks kroz dio zida (od T_1 do T_x): $$q_x(q)\left[W/m^2\right] = q_x(\mathbf{q}) = \frac{T_1 - T_x}{\frac{1}{\alpha_1} + \sum_1^2 \frac{\delta}{\lambda}}$$

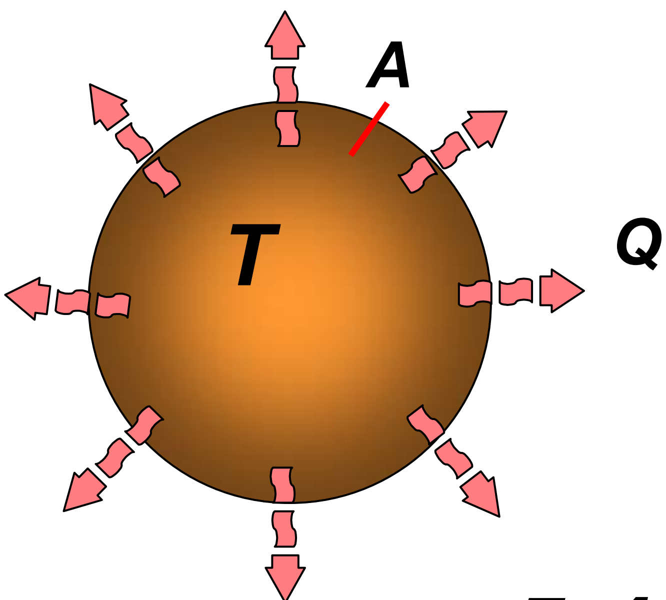
*Prvo nadjemo **q** iz prve jednačine, a onda odredimo T_x iz druge zamjenjujući $q_x=q$.*

PROSTIRANJE TOPLOTE

Zračenje

Zračenje je elektromagnetni fenomen (kao svjetlost). Svako tijelo zagrijano iznad apsolutne nule, zrači.

FLUKS KOJI ZRAČI TIJELO:



$$\dot{Q}_R \approx A \varepsilon \sigma T^4 \; [W]$$

$A \; [m^2]$ - Površina

$0 < \varepsilon \; [-] < 1$ – Koeficijenat emisije

$T \; [K]$ - Apsolutna temperatura

$\sigma = 5.44 \; 10^{-8} \; W/m^2K^4$ – Stefan-Bolcmanova konstanta

PROSTIRANJE TOPLOTE

Zračenje

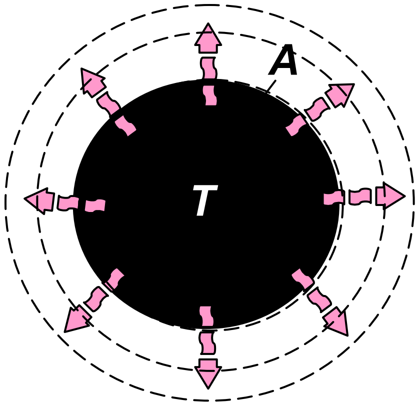
CRNO TIJELO

- ***najbolji Emiter,*** $\mathcal{E}$ **=1**
- ***najbolji Apsorber, a=1***

$$\dot{Q}_R^b\,[W] \approx A\,\sigma\,T^4$$

$\mathcal{E}$ – *koeficijent emisije*

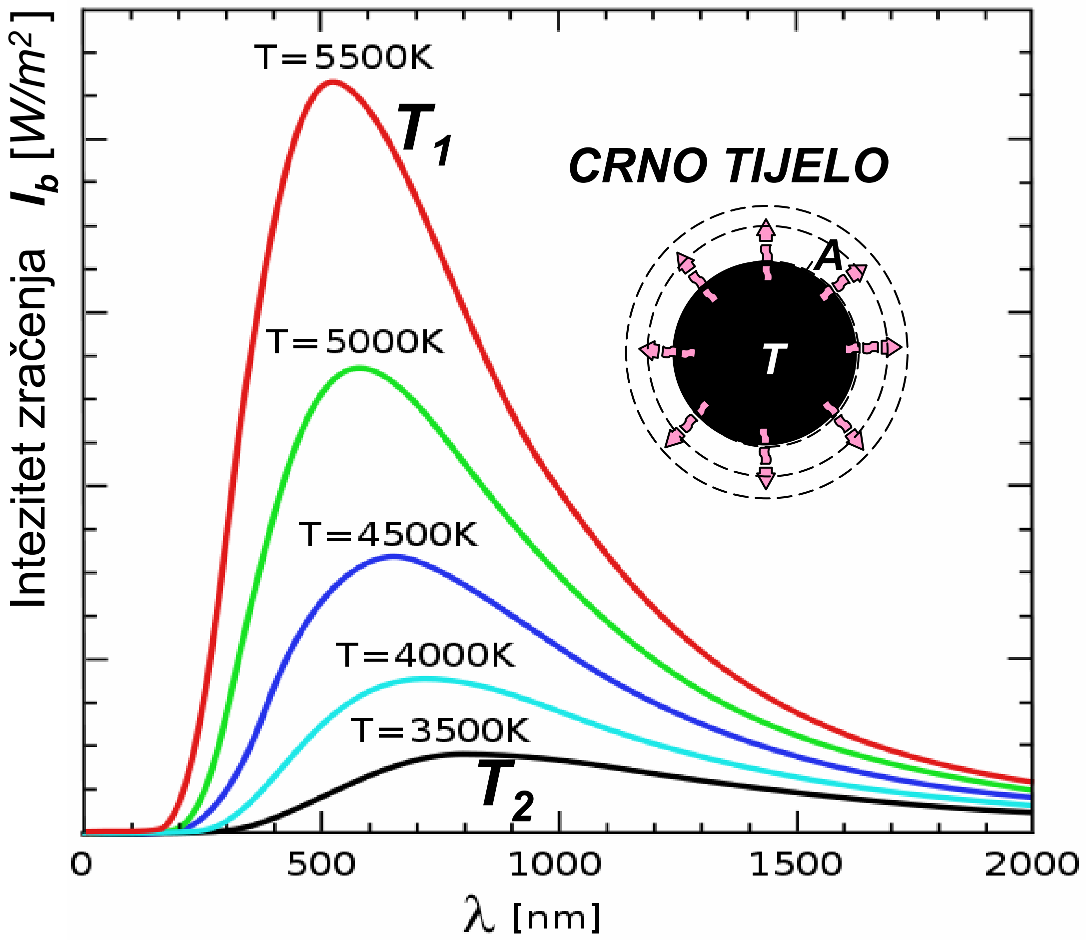
a – *koeficijent apsorpcije*



$$a \approx \varepsilon$$

PROSTIRANJE TOPLOTE

Zračenje



Što je tijelo zagrijanije (viša T) ono zrači više u kratkotalasnom spektru (T_1) i obrnuto (T_2).

PROSTIRANJE TOPLOTE *Zračenje*

SIVO TIJELO

ε – *koeficijent emisije*

a – *koeficijent apsorpcije*

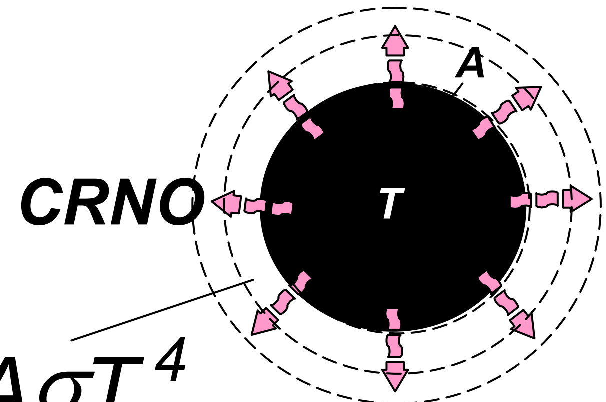
$$0 < \varepsilon = \mathbf{a} < 1$$

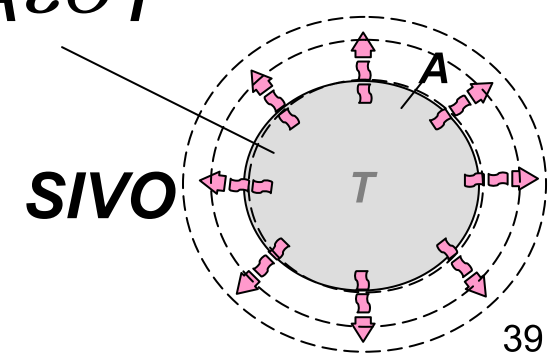
$$\varepsilon = \dot{Q}_R^s / \dot{Q}_R^b$$

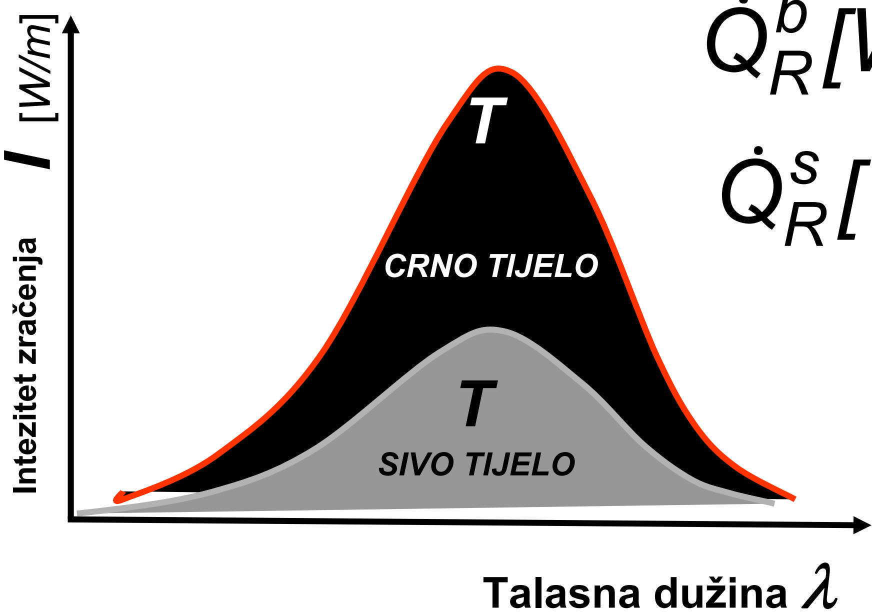
$$\dot{Q}_R^s = \varepsilon \ \dot{Q}_R^b$$

$$\dot{Q}_R^b [W] \approx A \sigma T^4$$

$$\dot{Q}_R^s [W] \approx A \varepsilon \sigma T^4$$

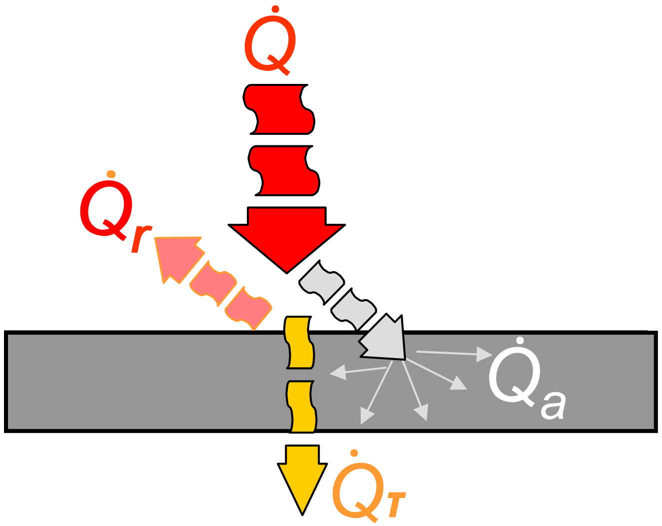






PROSTIRANJE TOPLOTE

Zračenje ***SIVO TIJELO***



$$\dot{Q} = \dot{Q}_a + \dot{Q}_r + \dot{Q}_d \,/\, \dot{Q}$$

$$1 = \dot{Q}_a / \dot{Q} + \dot{Q}_r / \dot{Q} + \dot{Q}_d / \dot{Q}$$

$$1 = a + r + \tau$$

a – koeficijenat apsorpcije

r – koeficijenat refleksije

τ – koeficijenat propustljivosti

Za CRNO TIJELO

a =1, r = 0, τ = 0

Za SIVO (neprozirno) TIJELO

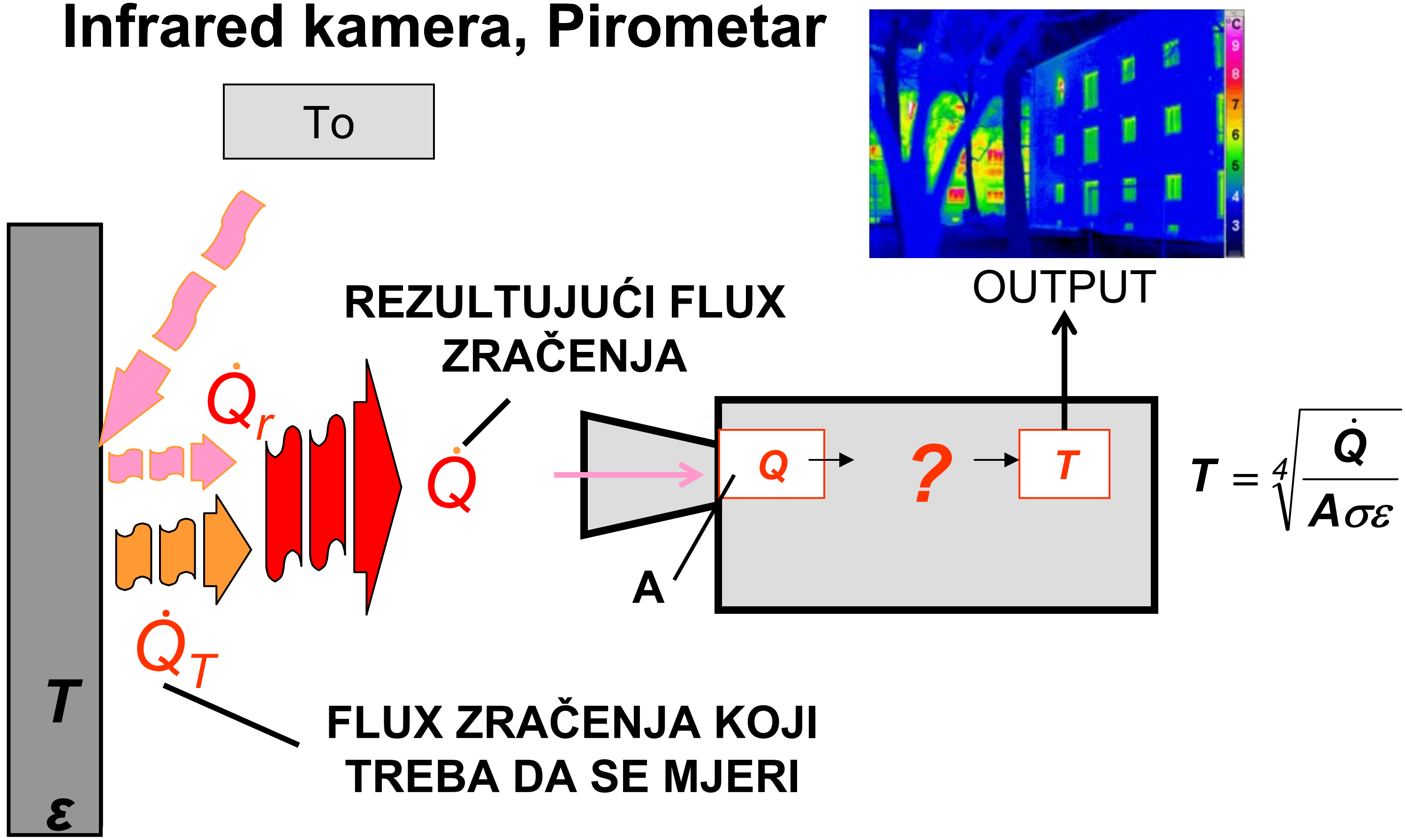
a <1, r = >0, τ = 0

Za SIVO (prozirno) TIJELO

a <1, r = >0, τ > 0

PROSTIRANJE TOPLOTE

Infrared kamera, Pirometar

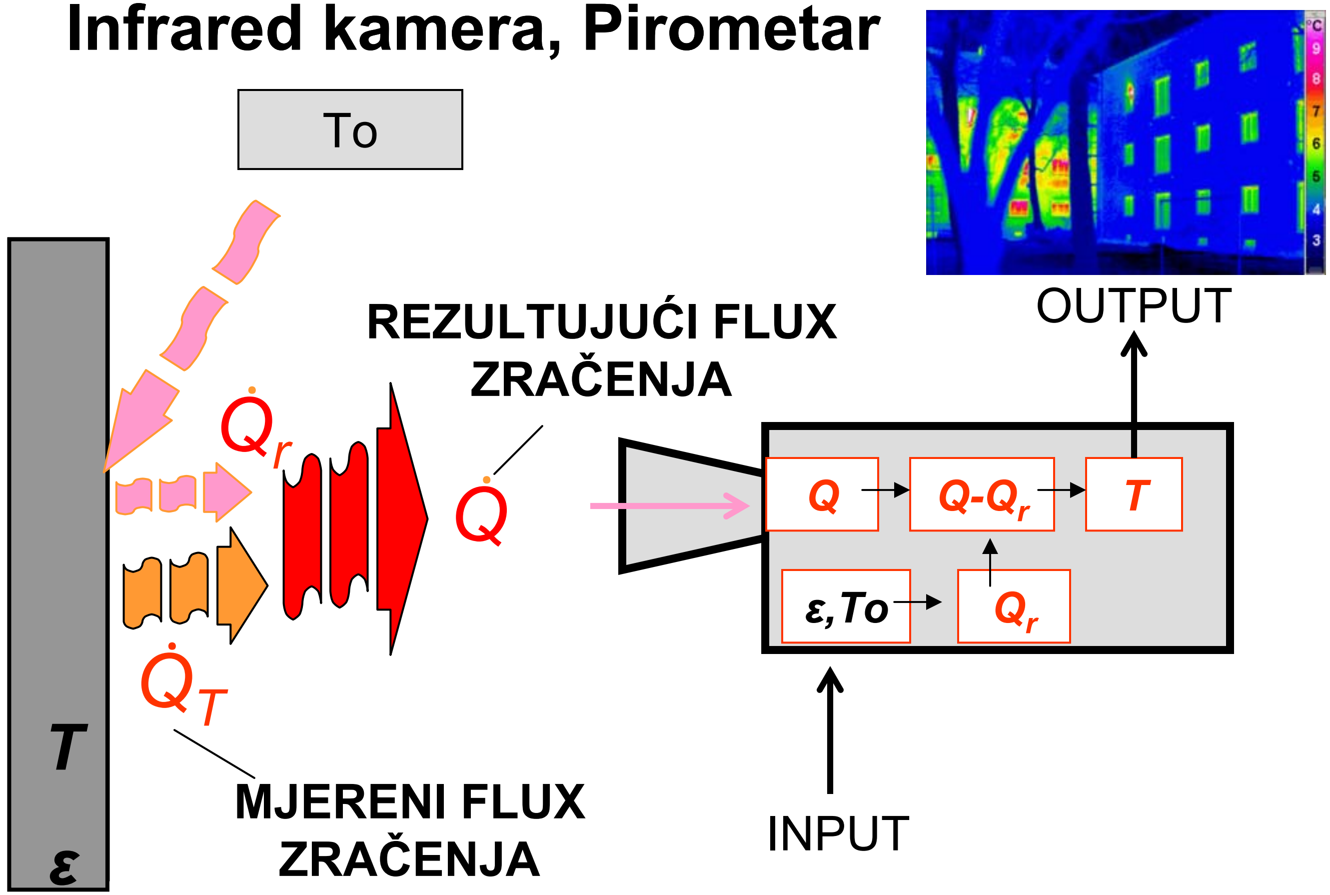


Da bi odredili ***T*** površine treba da izmjerimo $\dot{Q}_T \approx A\varepsilon\sigma T^4$

Medjutim kamera “hvata” ukupni fluks zračenja **Q** koji sadrži i reflektovanu komponentu Q_R, tj. kamera hvata $Q = Q_T + Q_R$

PROSTIRANJE TOPLOTE

Infrared kamera, Pirometar



Kako odrediti (eliminisati) Q_r?

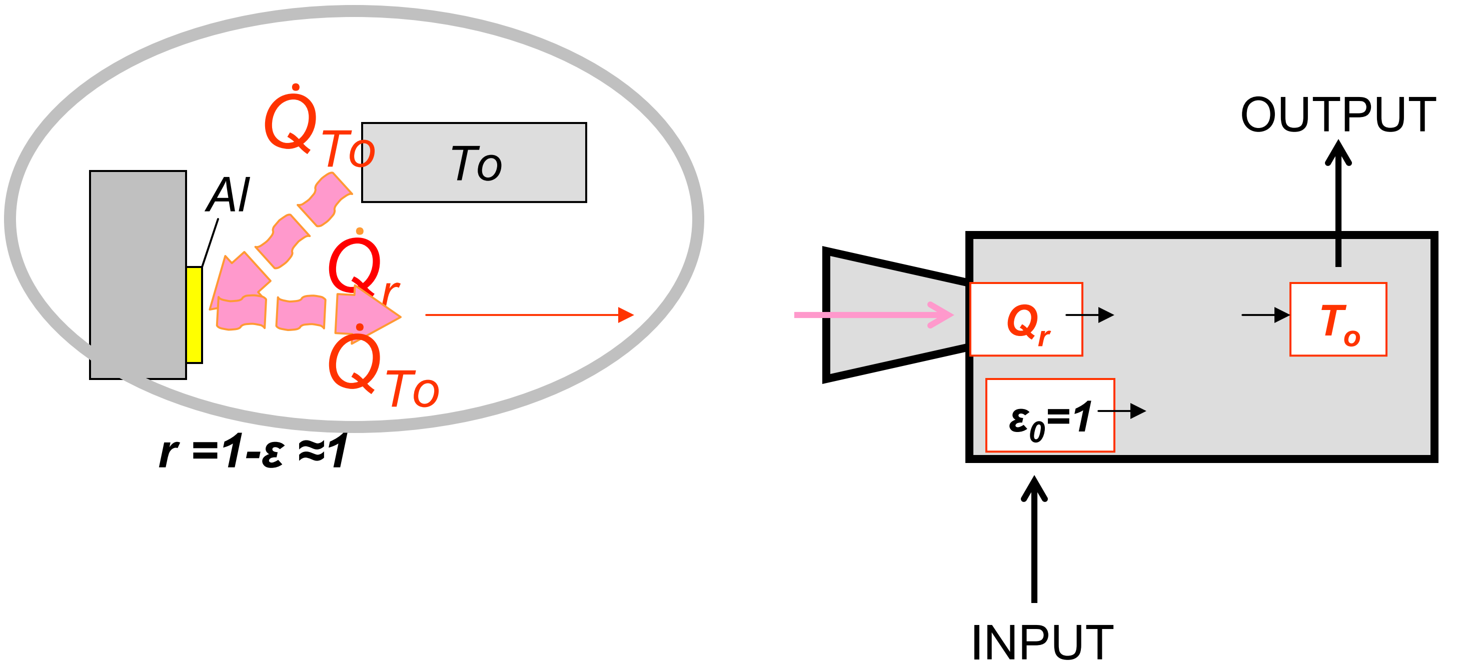
a. Izmjeri se temperatura okoline (*To*) i kamera odredjuje Q_r koristeći uneseni ***ε,*** jer je

$$Q_r = Ar\sigma T_o^4 = A(1-\varepsilon)\sigma T_0^4$$

Kada se taj fluks oduzme od ukupnog Q, dobija se traženi Q_T, odnosno temperatura ***T***.

PROSTIRANJE TOPLOTE

Infrared kamera, Pirometar

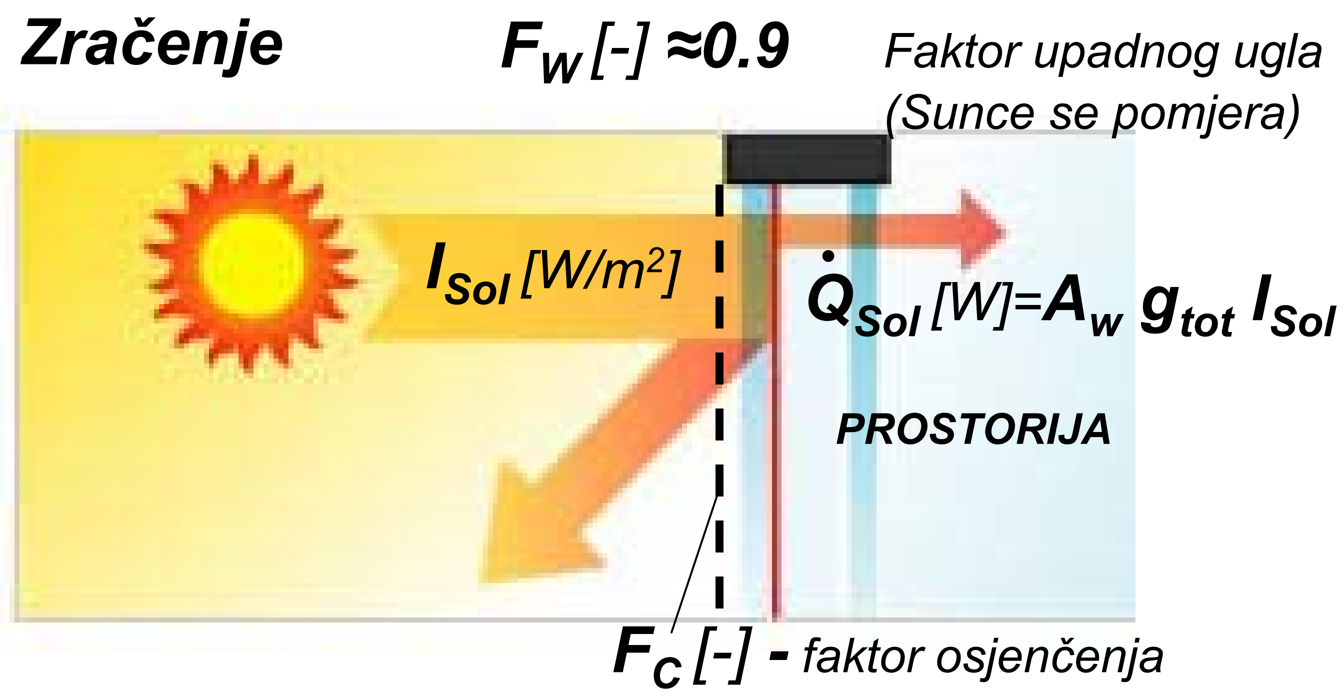


Kako odrediti (eliminisati) Q_r?

b. Temperatura *To* se odredjuje kamerom tako što se kamerom izmjeri reflektovano zračenje, odnosno zračenje okoline. Kako se to izvodi?

Postavi se ***Al*** folija (malo $\varepsilon_{Al} = 0.04 \approx 0$, *tj.* $r \approx 1$, pa se svo zračenje okoline Q_{To} reflektuje kao u ogledalu); tako kamera "vidi"samo okolinu i pokazuje njenu efektivnu temperaturu okoline ***To***.

PROSTIRANJE TOPLOTE



$g_\perp$ - stepen propustljivosti zastakljenja pri normalnom upadu zračenja

A_w [m²] - Površina prozora (providni dio)

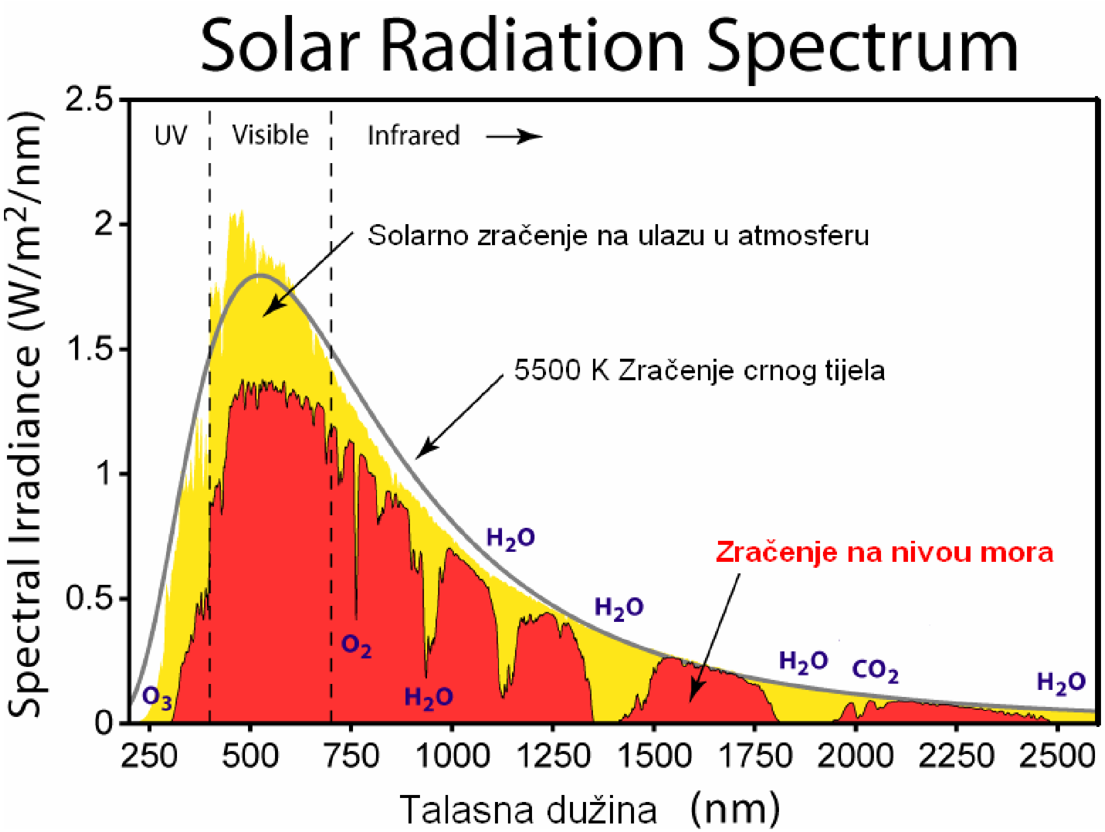
g_{tot} [-] =F_W F_C $g_\perp$ –Ukupni faktor Solarnih dobitaka

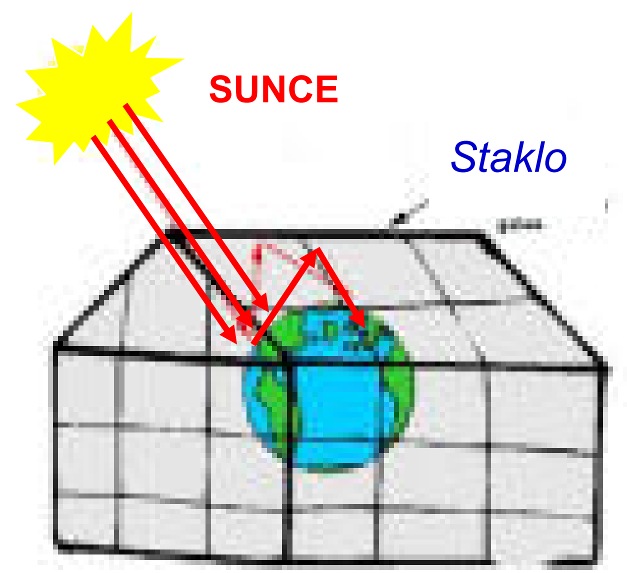
I_{Sol} [W/m²] – Specifični Solarni fluks (funkcija orjentacije površine)

PROSTIRANJE TOPLOTE

Zračenje

Globalno zagrijavanje: Efekat “staklene bašte”



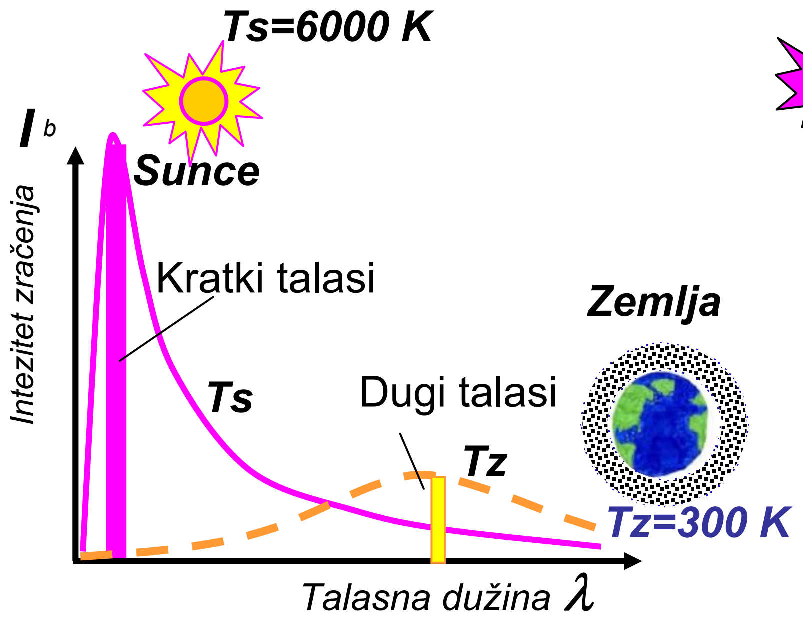


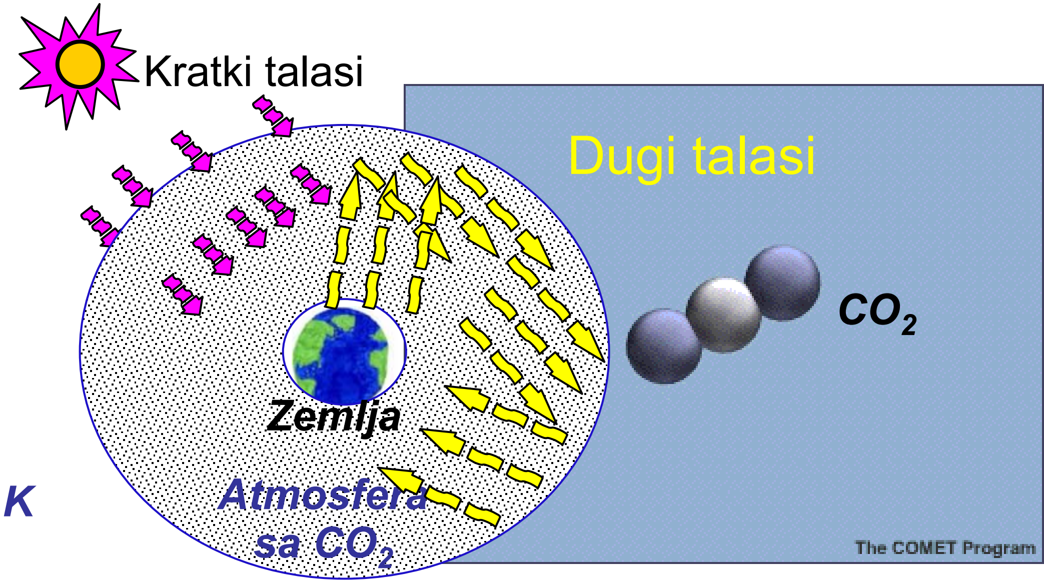
Staklo propušta kratkotalasno zračenje Sunca a ne propušta dugotalasno zračenje.

PROSTIRANJE TOPLOTE

Zračenje

Globalno zagrijavanje
Efekat "staklene bašte"





CO_2 se ponaša kao staklo:
Propušta kratkotalasno zračenje Sunca a ne propušta dugotalasno zračenje Zemlje (zagrijane Suncem).