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Total Emissive Power

If we want total power emitted by a radiating body over all wavelengths, we need to integrate over the whole spectrum:

$$e_b = \int_0^\infty e_{b,\lambda}\, d\lambda = T^5 C_1 \int_0^\infty \frac{(\lambda T)^{-5}}{\exp\left(C_2/\lambda T\right) - 1}\, d\lambda$$

$$= T^4 \underbrace{\left[C_1 \int_0^\infty \frac{\eta^5}{e^{C_2/\eta} - 1}\, d\eta \right]}_{\boxed{\sigma = 5.67\times10^{-8}\ W/m^2\cdot K^4}} \quad ; \quad \eta = \lambda T$$

↳ Stefan-Boltzman constant

So our total emissive power is simply:

$$\boxed{e_b = \sigma T^4} \Rightarrow T \text{ is in Kelvin!}$$

↳ This is a heat flux $[W/m^2]$.

Note, the previous analysis is only valid for ideal emitters.

Ideal Emitter <=> "Blackbody"

1) Blackbodies absorb all incoming radiation

2) Radiation is independent of direction (Diffuse) 

3) At a given temperature, T, no surface can emit more energy than a blackbody.

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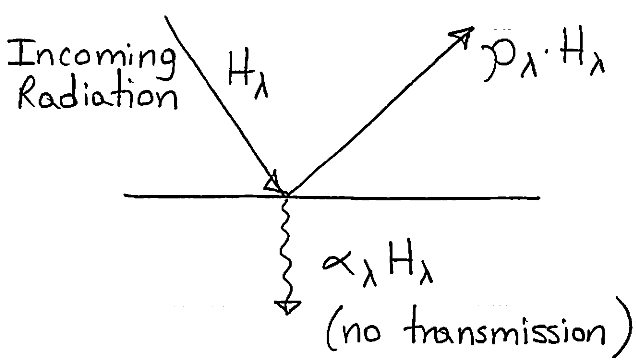
For non-blackbody surfaces (real surfaces), we can deffine a monochromatic emmisivity, ε_λ

$$e_\lambda = \varepsilon_\lambda \cdot e_{b,\lambda}$$

$$e = \int_0^\infty \varepsilon_\lambda e_{b,\lambda} \, d\lambda = \varepsilon \cdot e_b$$

$$\boxed{\varepsilon = \frac{\int_0^\infty \varepsilon_\lambda \cdot e_{b,\lambda} \cdot d\lambda}{\int_0^\infty e_{b,\lambda} \, d\lambda}}$$ $\Rightarrow$ Spectrally averaged emmisivity

In real life, we also have reflection (ρ) and absorption (α)



An energy balance:

$$\boxed{\rho_\lambda + \alpha_\lambda = 1}$$

In thermal equilibrium:

$$\boxed{\varepsilon_\lambda = \alpha_\lambda}$$ Kirchoff's Law

Similarly for absorption:

$$\boxed{\alpha = \frac{\int_0^\infty \alpha_\lambda H_\lambda \, d\lambda}{\int_0^\infty H_\lambda \, d\lambda}}$$ $\Rightarrow$ Spectrally averaged absorptivity

From <u>Kirchoff's Law</u> we can say:

1) Good absorbers are good emitters
2) Poor absorbers are poor emitters

$\}$ Experimentally observed!

Note, if we have transmission (τ_λ) $\Rightarrow$ $\boxed{\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1}$

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Example | A car accident injures a passanger at night and to help save bodyheat, the EMT's drape the passanger in an aluminum blanket. Assume $T_\infty = -50°C$, and $\varepsilon_{Blankel} = 0.10$. How much heat loss is saved?

This is a very common technique to limit radiative losses, exspecially at night:

Assume your body temperature is at 37°C

$$e_b = \sigma T^4 = (5.67\times10^{-8})\left[(37+273.15)^4 - (-50+273)^4\right]$$

emission from atmosphere to you.

$$\boxed{e_b = 384.05\ W/m^2}$$

Now if we drape the aluminum blanket:

$$e_b = \varepsilon_{blanket}\cdot\sigma T^4 = (0.10)(5.67\times10^{-8})(310^4 - 223^4)$$

$$\boxed{e_b = 38.3\ W/m^2}$$

So how does this compare to convection? Lets assume $T_{air} \approx 5°C$, and $h_{conv} = 20\ W/m^2\cdot K$ (light breeze)

$$q''_{conv} = h\Delta T = (20\ W/m^2K)(37°C - 5°C)$$

$$\boxed{q''_{conv} = 640\ W/m^2}$$

So we can see that both radiation & convection are very important mechanisms and that draping the reflective aluminum blanket lowers losses by about 35%.