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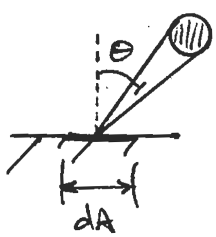
KEY CONCEPTS FROM LAST TIME –

- BLACKBODY
- PLANCK'S LAW
- WIEN'S DISP. LAW
- STEFAN – BOLTZMANN LAW
- SOLID ANGLE
- INTENSITY
- EMISSIVE POWER



$$I_\lambda = \frac{\text{POWER IN CONE}}{\text{PROJECTED AREA}} = \frac{P_\lambda'}{dA_\perp \, d\lambda \, d\Omega} = \frac{P_\lambda'}{dA \cos\theta \, d\lambda \, d\Omega}$$

$$P_\lambda' = I_\lambda \, dA \cos\theta \, d\lambda \, d\Omega$$

$$P_\lambda = \int_\Omega I_\lambda \, dA \cos\theta \, d\lambda \, \underbrace{d\Omega}_{\sin\theta \, d\theta \, d\phi}$$

$$E_\lambda = \frac{P_\lambda}{dA \, d\lambda} = \int_0^{\pi/2} d\theta \int_0^{2\pi} I_\lambda \cos\theta \sin\theta \, d\phi$$

$$E_{b\lambda} = \pi I_{b\lambda}$$

LAMBERT'S LAW $\Longrightarrow$ LAMBERTIAN SURFACE   15 62
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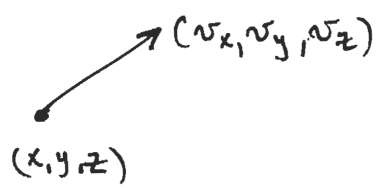
INTENSITY IS A SCALAR !

WHY DOES IT VARY IN DIFFERENT DIRECTIONS ?



PHASE SPACE

$$f(x, y, z, v_x, v_y, v_z, t)$$

DIST. FUNCT.

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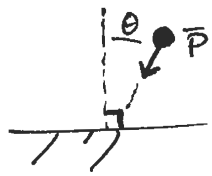
HOW TO MAKE A BLACK BODY

RADIATION PRESSURE

$$F\Delta t = \Delta P = \Delta m v \quad \text{, NO REST MASS SO } P = \frac{h}{\lambda}$$



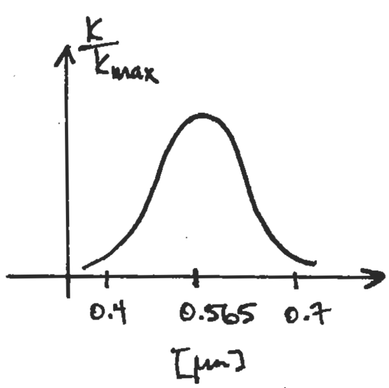
$$P_r = \int_{\Omega} \frac{I_\lambda}{h\nu} \cdot \frac{h}{\lambda} \cos\theta \, d\Omega = \frac{2\pi}{3c} I_{b\lambda}$$

$$\boxed{P_r = \frac{2E_b}{3c}}$$ $\Leftarrow$ ONLY FOR INCOMING RADIATION (absorbed)

$$\frac{2}{3} \cdot \frac{5.67\times10^{-8} \cdot 10^{4}}{3\times10^{8}} \sim 10^{-4} \frac{N}{m^2}$$

FOR VISIBLE LIGHT $\Longrightarrow$ LUMINOUS INTENSITY

$$L_\lambda = \underbrace{K_\lambda}_{\text{LUMINOUS EFFICACY}} I_\lambda \qquad K_{max} = 683 \frac{Lm}{W}$$



* FOR 60W LIGHTBULB

$\Longrightarrow$ 840 lumen

$\Longrightarrow$ 3W

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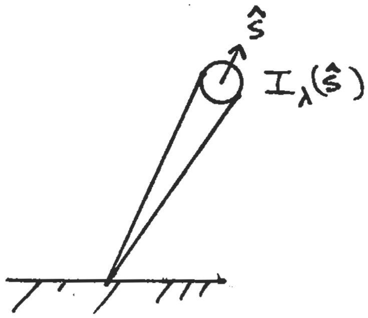
REAL SURFACES

EMISSIVITY



PRIME DENOTES DIRECTIONALITY

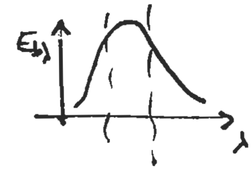
$$\varepsilon_\lambda' = \frac{I_\lambda \cos\theta \, dA \, d\lambda \, d\Omega}{I_{b\lambda} \cos\theta \, dA \, d\lambda \, d\Omega} \quad \text{\} POWER IN CONE}$$

$$\varepsilon_\lambda' = \frac{I_\lambda}{I_{b\lambda}}$$ "SPECTRAL-DIRECTIONAL EMISSIVITY"

$\varepsilon_\lambda \equiv$ SPECTRAL-HEMISPHERICAL $\Rightarrow$ $\varepsilon_\lambda = \frac{1}{\pi} \int_\Omega \varepsilon_\lambda' \cos\theta \, d\Omega$

$\varepsilon' \equiv$ TOTAL-DIRECTIONAL $\Rightarrow$ $\varepsilon' = \frac{1}{n\sigma T^4} \underbrace{\int_0^\infty \varepsilon_\lambda' E_{b\lambda}(T,\lambda) \, d\lambda}_{\text{WEIGHTED BLK BDY AVG.}}$

$\varepsilon \equiv$ TOTAL-HEMISPHERICAL



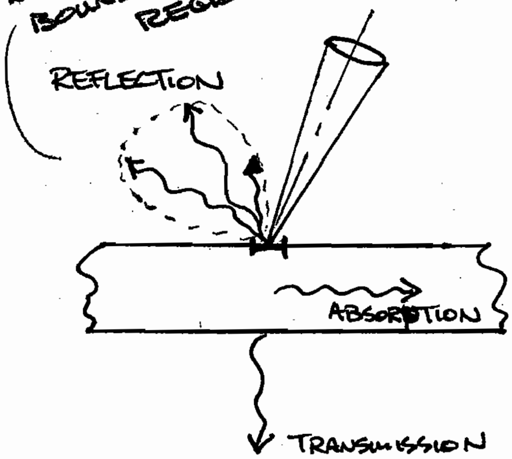
DIFFUSE $\varepsilon_\lambda' = \varepsilon_\lambda$

GRAY $\varepsilon_\lambda' = \varepsilon'$

$\Rightarrow$ DIFFUSE-GRAY $\varepsilon_\lambda' = \varepsilon$ (IDEAL SITUATION)

ABSORBING SURFACES

REFLECTION COULD BE BOUND BY A PARTICULAR REGION



$$P_\lambda' = I_\lambda \cos\theta \, dA \, d\lambda \, d\Omega$$

ABSORPTIVITY

$$\alpha_\lambda' = \frac{H_{a\lambda}'}{I_\lambda \cos\theta} = \frac{H_{a\lambda}'}{\underbrace{H_\lambda'}_{\text{SPECTRAL DIR. IRRADIATION}}}$$

$\alpha_\lambda'(T, \theta, \psi, \lambda)$

α_λ

α'

α

REFLECTIVITY

$\rho_\lambda''(\lambda, \hat{s}_i, \hat{s}_r)$ SPECTRAL-BIDIRECTIONAL REFLECTIVITY

$$\rho_\lambda'' = \frac{dI_\lambda(\lambda, \hat{s}_i, \hat{s}_r) \text{ (OUTGOING)}}{I_\lambda(\lambda, \hat{s}_i)\cos\theta_i \, d\Omega_i \text{ (INCOMING POWER)}}$$

$\rho_\lambda'^{\triangle}$ SPECTRAL-DIRECTIONAL-HEMISPHERICAL EMISS.

$$\rho_\lambda'^{\triangle} = \frac{\int_\triangle dI_\lambda \cos\theta_r \, d\Omega_r}{H_\lambda' \, d\Omega_i}$$

IF ρ_λ'' CONSTANT

$$= \int_\triangle \rho_\lambda'' \cos\theta_r \, d\Omega_r = \pi \rho_\lambda''$$

$\Downarrow$

WILL GET 8 VERSIONS, BECAUSE NOW, REFLECTION IS DIRECTIONALLY DEPENDANT.

FROM AN NRG BALANCE

$$\rho + \alpha + \tau = 1$$

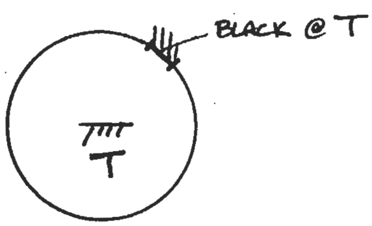
$$\rho_\lambda'^{\Delta} + \alpha_\lambda' + \tau_\lambda'^{\Delta} = 1$$

IF OPAQUE, THEN $\tau = 0$, AND $\rho + \alpha = 1$

KIRCHOFF'S LAW

$$\varepsilon_\lambda'(T,\theta,\phi) = \alpha_\lambda'(T,\theta,\phi)$$

A FORM OF "PRINCIPLE OF DETAILED BALANCE"



$$\varepsilon_\lambda' \cancel{E_{b\lambda}(T)} = \alpha_\lambda' \cancel{E_{b\lambda}(T)}$$

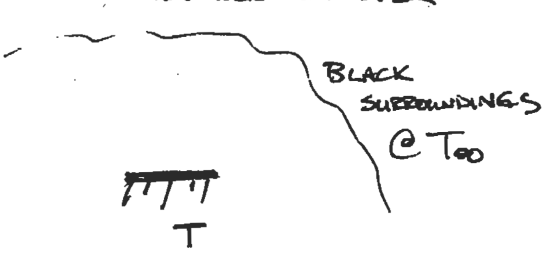
IF LINEAR, ONLY EMITTER TEMP. MATTERS

IF DIFFUSE GRAY $\Rightarrow$ $\varepsilon = \alpha$

** IF GEOMETRY OF STRUCTURE IS IMPORTANT, PPL. WILL USE (e.g. SURFACE ROUGHNESS, COATINGS, OR THICKNESS)

"TRANSMITTANCE"
"REFLECTANCE"
"ABSORPTANCE"
"EMITTANCE"

RADIATION TRANSFER

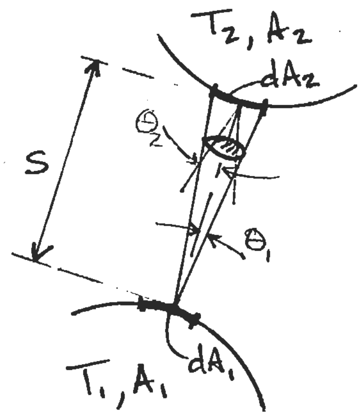


$$q'' = \varepsilon E_b(T) - \alpha E_b(T_\infty)$$

$$= \varepsilon\sigma(T^4 - T_\infty^4)$$

SANITY CHECK $\Rightarrow$ WHEN $T = T_\infty$ NO HEAT TRANSFER

FOR 2 SURFACES . . .



$$I = \frac{P'}{\cos\theta_1 \, dA_1 \, d\Omega_1} \quad , \; L = \frac{\cos\theta_2 \, dA_2}{S^2}$$

$$P' = I \, dA_1 \cos\theta_1 \, d\Omega_1$$

$$P_{TOT} = \pi I \, dA_1$$

$$F_{dA_1 - dA_2} = \frac{P'}{P_{tot}} = \frac{\cos\theta_1 \cos\theta_2}{\pi S^2} dA_2$$ "view factor"