Consider the flow of a gas with density 1 kg/m3 viscosity 15×10^{-5} kg/(m s), spec. heat $C_p = 846$ J/kg.K and k = 0.01665 W/m.K in a pipe of diameter D = 0.01m and length L = 1m, and assume the viscosity doesn't change with temperature.

The nusselt number for a pipe with $Re.Pr.D/L$ L/D ratio greater than 10 and Reynold's number greater than 20000 is given by

$$Nu = 0.026\ Re^{0.8}\ Pr^{1/2}$$

While Nu no. for laminar flow for Reynold's number less than 2100 and (Re Pr D/L) < 10 is

$$Nu = 1.86\ [Re.Pr\ (D/L)]^{1/3}$$

if the gas flows through pipe with an average velocity of 0.1 m/s and h is

(a) 0.68 W/m²K. (b) 1.14 W/m²K.

(c) 2.47 W/m²K (d) 24.7 W/m²K

A) $Re = \frac{DV\rho}{\mu} = \frac{0.01 \times 0.1 \times 1}{1.5 \times 10^{-5}} = 66.7$

$Pr = \frac{C_p \mu}{k} = \frac{846 \times 15 \times 10^{-5}}{0.01665} = 0.76$

$Re \cdot Pr \cdot D/L = 66.7 \times 0.76 \times 0.01/1 = 0.507$

$Nu = 1.86 \left(Re \cdot Pr \, (D/L) \right)^{1/3} = 1.86 \times (0.507)^{1/3} = 1.483$

$Nu = \frac{hD}{K}$

$h = \frac{Nu \times K}{D} = \frac{1.483 \times 0.01665}{0.01} = 2.47 \ W/m^2K$ (c)

Law of Radiation

Kirchoff's law

It states that the emissivity of the surface is equal to it's absorptivity when the surface or the body is in thermal equillibrium with it's surrounding

- inside surface is vaccum, so the heat transfer occuring only through radiation

$\alpha = \epsilon$

The rate of energy absorbed = rate of energy emitted

$I \cdot A_1 \cdot \alpha_1 = E_1 \cdot A_1$ I - incident radn

$I = \frac{E_1 A_1}{\alpha_1 \times A_1} = \frac{E_1}{\alpha_1}$ —— (1)

$2 \to I . A_2 . \alpha_2 = E_2 A_2$

$$I = \frac{E_2}{\alpha_2} \quad \text{—} \ ②$$

From ① & ②

$$I = \frac{E_1}{\alpha_1} = \frac{E_2}{\alpha_2}$$

$$I_{bla} = \frac{E_b}{\alpha_b}$$

for black body $\alpha = \infty$

$$I_b = \frac{E}{\alpha} = E_b$$

$$\boxed{\alpha = \frac{E}{E_b}} \quad \text{—} \ ⓐ$$

Absorptivity $\to \frac{Q_a}{Q}$ $= \varepsilon$

Emissivity $\to \frac{E}{E_b}$

From eq ⓐ $\longrightarrow \frac{E}{E_b} = \alpha$

$$\boxed{\varepsilon = \alpha}$$

Conditions – Temp & λ should be const

$$\varepsilon_\lambda = \alpha_\lambda$$

direction should also be same

$$\varepsilon_{\lambda\theta} = \alpha_{\lambda\theta}$$

Appl^n — Black body approximation

Plank's law

- It is given as the relationship between monochromatic emissive power & its wavelength
- Based on quantum theory

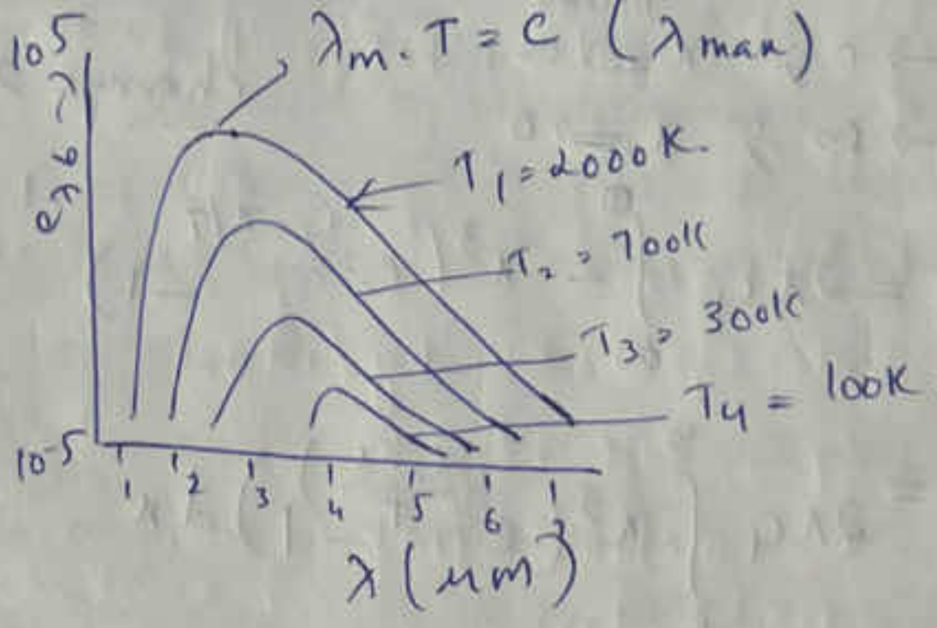
$$e_{b\lambda} = \frac{2\pi c_1}{\lambda^5 \left[e^{(c_2/\lambda T)} - 1\right]} \quad W/m^2 \qquad T - \text{Abs. temp}$$

mono. e. p

$$c_1 = 2\pi h c_0^2$$

$$c_1 = 0.596 \times 10^{-16} \, W/m^2$$

$$c_2 = 1.438 \times 10^{-2} \, (mk)$$



1) $e_{\lambda b} \uparrow$ as λ till λ_{max} and $\downarrow$
2) $e_{b\lambda} \uparrow$, $T \uparrow$ for any λ
3) Thermal radiation - 0.3 - 10 μm

Stefan Boltzmann's law

$(e_b) \propto T^4$

Total emissive power of black body

$e_b = \sigma \cdot T^4$ $\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$

W/m^2

$-e_b = \int_0^\infty e_{b\lambda} \cdot d\lambda = \int_0^\infty \frac{2\pi c_1}{\lambda^5 (e^{c_2/\lambda T} - 1)} \cdot d\lambda$

Let, $x = 1/\lambda$, $\lambda = x^{-1}$ $\frac{-x^2}{x^{-5}}$

$\therefore dx = -\frac{1}{\lambda^2} d\lambda$, $d\lambda = -\lambda^2 \cdot dx$

becom

$\lambda \to 0$; $x \Rightarrow \infty$

change λ to x.

$\lambda \to \infty$; $x \Rightarrow 0$

$\therefore e_b = 2\pi c_1 \int_\infty^0 - x^3 (e^{c_2 \cdot x/T} - 1)^{-1} dx.$

(x^{-5})

$= 2\pi c_1 \int_0^\infty x^3 (e^{(\frac{c_2 \cdot x}{T})} - 1) \cdot dx$

$-x^3.$

$= \frac{\cancel{x^{-2}}}{\cancel{x}}$

$= \frac{-\lambda^2}{\lambda^5}$

$= \frac{x^{-2}}{x^{-5}} = \frac{1}{\lambda^3}$

x^3

$$e_b = 2\pi C_1 \int_0^\infty x^3 \left(e^{-C_2 x T} + e^{-2C_2 x \cdot T} + \ldots \right) \cdot dx$$

$$= 2\pi C_1 \int_0^\infty x^3 \cdot e^{-C_2 i (x/T)} \cdot dx \quad i = 1, 2, 3.$$

$$= 2\pi C_1 \left[\frac{3!}{} \right.$$

$$\boxed{e_b = 5.672 \times 10^{-8} T^4}$$

$$e_b = \sigma \cdot T^4$$

Act. emissive power, $\boxed{e_b = \sigma A T^4}$

A - surface area.

Gray Body Radiation

- It refers to the emission of electromagnetic radiation from an object that isn't a perfect black body radiator, but still emits radiation at all wavelength according to planck's law.
- Grey body absorbs only a fraction of the incident radiation and emits radiation at all wavelengths according to plancks law with a reduced intensity