TUTORIAL ON RADIATION

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1) Given $T = 44°C = 317\ K$, $\epsilon = 0.92$

$q = \epsilon A \sigma T^4$ (Stefan - Boltzman's law)

Thermal flux per square foot $\frac{q}{A} = \epsilon \sigma T^4$

$\frac{q}{A} = 0.92 \times 5.6697 \times 10^{-8} \times (317)^4 \ (Wm^{-2} . K^{-4})(K^4)$

$\frac{q}{A} = 526\ W/m^2$

Radiant thermal flux per square foot = 526 W/m²

2) Given , $q = 2200\ W/m^2$.

$q_a = 900\ W/m^2$

$q_r = 450\ W/m^2$

and $q = q_a + q_b + q_t + q_r$

$\Rightarrow \frac{q_a}{q} + \frac{q_r}{q} + \frac{q_t}{q} = 1$

$= a + r + t = 1$

$t = 1 - a - r = 1 - (0.409 + 0.204)$

$t = 0.387$

(3) Temperature $T = 115 + 273 = 388\ K$

(a) By Stefans Boltzman law,

Total emissive power $= \varepsilon_b = \sigma T^4$

$\sigma = 5.67 \times 10^{-8}\ wm^{-2}/k^4$

So,

$$\varepsilon_b = (5.67 \times 10^{-8}) \times (388)^4$$

$$\varepsilon_b = 1.285 \times 10^3\ w/m^2$$

(b) From Wien's Law

$$\lambda_{max} = \frac{0.0029}{T}\ km$$

$$\lambda_{max} = \frac{2.9 \times 10^{-3}}{388} \times m$$

$$\lambda_{max} = 7.47 \times 10^{-6}\ m$$

(c) By a combination of Planck's law & wien's law,

$$(\varepsilon\lambda)_{max} = 1.307 \times 10^{-5}\ T^5\ w/m^2$$

$$= \frac{c_1 (\lambda_{max})^{-5}}{exp\left[\frac{c_2}{\lambda_{max} T}\right]^{-1}}$$

$$= \frac{0.374 \times 10^{-15} \times (2.9 \times 10^{-3})^{-5}}{exp[1.4388 \times 10^{-2} / (2.9 \times 10^{-3})]^{-2}}$$

$$(\varepsilon\lambda)_{max} = 1.307 \times 10^{-5} \times T^5\ w/m^2$$

For given temp $T = 388 K$

$$(\varepsilon\lambda)_{max} = 1.307 \times 10^{-5} \times 388$$

$$= 1.15 \times 10^2\ w/m^2$$

4 (a) Radius of sun $= R = 6.96 \times 10^{8}$ m

Area of sun $= A = 4\pi R^2$

$$A = 4 \times 3.14 \times (6.96 \times 10^{8})^2$$
$$= 6.08 \times 10^{18} \ m^2$$

By Stephan - Boltzman law, $P = \sigma T^4$

$$P = 5.67 \times 10^{-8} \times (5700)^4$$
$$= 5.98 \times 10^{7} \ W/m^2$$

(b) Total power radiated $= P_{total} = PA = 5.98 \times 10^{7} \times 6.08 \times 10^{18}$

$$P_{total} = 3.6 \times 10^{26} \ W$$

5 (a) Given $T = 90^\circ F = 305 K$

By stefan Boltzman Law, $P = \sigma T^4$

$$= 5.67 \times 10^{-8} \times (305)^4$$
$$= 491 \ W/m^2$$

b) Peak wavelength $= \lambda_{max} = \dfrac{0.0029}{T}$

Wein's law $= \dfrac{2.9 \times 10^{-3}}{305}$ $\quad \lambda_{max} = 9.5 \times 10^{-6}$ m

(c) Total radiant energy for male $: E_{male} = 491 \times 1.9 = 932.9 \ W \approx 933 W$

Total radiant energy for females $: E_{female} = 491 \times 1.6 = 785.6 \ W \approx 786 W$

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Q (a) By Stefan Boltzman's law

$$\frac{dP}{dA} = \sigma T^4 , \sigma = 5.67 \times 10^{-8} \ W/m^2$$

Here $\frac{dP}{dA}$ is equal to the power radiated per unit surface area

$$\int dP = \int \sigma T^4 . dA \quad \text{(integrating both sides w.r.t A)}$$

$P_{total} = A . \sigma T^4$ (A = surface area)

$P_{total} = 2\pi r . \sigma . T^4$

$= 2 \times 3.14 \times 0.05 \times 10^{-3} \times 0.02 \times 5.67 \times 10^{-8} \times 5000$

$= 220 \ W$

(b) $P_{eye} = P_{total} \frac{\times \pi (3 \times 10^{-3})^2}{4\pi (10 \times 10^3)^2}$

$P_{eye} = 4.95 \times 10^{-12} W$

(c) wien's law, $\lambda_{max} = \frac{2.9 \times 10^{-3}}{5000}$

$= 5.8 \times 10^{-7} m = 580 \ nm$

$\lambda_{max} = 580 \ nm$

(d) Energy of a photon = $E_p = \frac{hc}{\lambda}$

No of photons = $N_p = \frac{P_{ey}}{E_p} = \frac{4.95 \times 10^{-12} \times 600 \times 10^{-3}}{6.63 \times 10^{-34} \times 3 \times 10^8}$

photons per second = 1.5×10^7