Part J Problems

1. The rate at which heat passes through a living room wall facing the outdoors is 6000 W. Its thickness is 0.10 m, and the outside temperature is 20 C^o lower than the inside temperature. The wall has an area of 24 m^2. What is the thermal conductivity of the wall?

2. The rate at which heat passes through a wall is 4200 J/s. If the wall's thickness were tripled, its area cut in half, and its thermal conductivity reduced to one tenth of its previous value, what then would be the rate at which heat passes through the wall, in J/s?

3. A cylinder's radius is the same as its height. It is radiating 8000 W. After it's cut in half, creating two shorter cylinders, what will be the total IR energy radiated?

4. At what Kelvin temperature must the surface of a sphere of radius 0.40 m be in order that it emit 20,000 watts of IR radiation? (Assume e = 1.)

5. An object with emissivity 0.40 has a surface area of 1.3 m^2. Its surface temperature is 300 K. What would be the net loss in energy, emission less absorption of infra-red radiation, in two hours if it were submerged in water at 280^{o}K? (Assume negligible temperature change.)

6. If a spherical star is radiating infra-red at a rate R, what would be the radiation rate if the star collapsed to a diameter one-fourth of the original diameter, which causes the Kelvin temperature to double?

7. The table below shows the mass per cubic meter of water vapor that "saturates" the air. Suppose the current temperature is 20 ^{o}C, and the water vapor content is 11 grams/m^3.
(a) What is the humidity? (b) What will be the humidity if the water vapor content doesn't change and the temperature later rises to 25 ^{o}C? (c) If the temperature falls to 10 ^{o}C, how many grams of water vapor per cubic meter will condense?

Temperature (^{o}C)	Maximum Number of Grams Allowed per Cubic Meter
10	8
20	17
25	20
30	30

Solutions

1. $k(24)(20)/0.10 = 6000$

$k = 1.25$ W/m-C^o

2. $R_1 = kA_1\Delta T/L_1$

$= 4200$ J/s

$L_2 = 3L_1$

$A_2 = A_1/2$

$k_2 = k_1/10$

$R_2 = k_2A_2\Delta T/L_2$

$= (k_1/10)(A_1/2)\Delta T/(3L_1)$

$= (1/60)\, k_1A_1\Delta T/L_1$

$= (1/60)\, 4200$

$= 70$ J/s

3. A_1 = Top area + Bottom Area + Side Area

$A_1 = \pi r^2 + \pi r^2 + 2\pi rh$

$h = r$

$A_1 = \pi r^2 + \pi r^2 + 2\pi r\,(r)$

$= 4\pi r^2$

Cutting in half adds two more circular areas:

$A_2 = A_1 + 2\pi r^2$

$= 4\pi r^2 + 2\pi r^2$

$= 6\pi r^2$

Ratio of Areas $= A_2/A1$

$= 6/4$

Ratio of Rates $= 6/4$

$R_2/R_1 = 6/4$ (Proof later)

$R_2/8000 = 6/4$

$R_2 = 12{,}000$ W

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Proof that $R_2/R_1 = 6/4$:

$R_1 = \sigma eA_1T^4$

$= \sigma e(4\pi r^2)T^4$

$= 8000$ W

$R_2 = \sigma eA_2T^4$

$= \sigma e(6\pi r^2)T^4$

$R_2/R_1 = \sigma e(6\pi r^2)T^4 / \sigma e(4\pi r^2)T^4$

$= (6/4)$

$R_2 = (6/4)\, R_1$

$= (6/4)\, 8000$

$= 12{,}000$ W

4. $5.67 \times 10^{-8}\,(1.0)4\pi(0.40)^2T^4 = 20000$

$T = 647\ ^oK$

5. $5.67 \times 10^{-8}\,(0.40)(1.3)(300^4 - 280^4) = 57.60$ W

6.

$R_1 = \sigma eA_1T_1^4$

$= \sigma e\,(4\pi r_1^2)T_1^4$

$R_2 = \sigma eA_2T_2^4$

$= \sigma e\,(4\pi r_2^2)T_2^{\,4}$

$r_2 = 1/4\, r_1$

$T_2 = 2T_1$

$R_2/R_1 = (r_2^2/r_1^2)\,(T_2^4/T_1^4)$

$= (r_2/r_1)^2\,(T_2/T_1)^4$

$= (1/4)^2\,(2)^4$

$= 1$

$R_2 = R_1$

7. (a) $H = (11/17)\,100$

$= 64.7\%$

(b) $H = (11/20)\,100$

$= 55.0\%$

(c) 11 grams per cubic meter are present, but only 8 grams are allowed at 10 ^{o}C, so 3 grams condense.