1. Part - A.

If heat is added to a liquid from a submerged solid surface, the boiling process referred to as pool boiling. In this case the liquid above the hot surface is essentially stagnant.

2. In drop wise condensation, a large portion of the area of the plate is directly exposed to vapour.

The heat transfer rate in drop wise condensation is 10 times higher than in film condensation.

3. The types of heat exchangers are as follows,

(i) Direct contact heat exchangers.
(ii) Indirect contact heat exchangers.
(iii) Surface heat exchangers.
(iv) Parallel flow heat exchangers.
(v) Counter flow heat exchangers.
(vi) Cross flow heat exchangers.
(vii) Shell and tube heat exchangers.
(viii) Compact heat exchangers.

4. The emissive power of a black body is proportional to the fourth power of absolute temperature

$$E_b \propto T^4$$

$$E_b = \sigma T^4$$

where,

E_b = Emissive power W/m^2

σ = Stefan Boltzmann constant $= 5.67 \times 10^{-8}\ W/m^2$

T = Temperature, K.

5. ~~The energy emitted by a surface at a given length per unit time per unit area in all directions~~

The total amount of radiation emitted by a body per unit time and unit area is called emissive power.

Part - B.

13. A) 11 A) Given data:

Boiling

water – copper

$d = 0.38m.$

$T_w = 115°c.$

To find:

(i) Power (Q)

(ii) rate of evaporation (m)

(iii) Critical flux

Solution:

from HMTDB. 30 for $T_{sat} = 100°c.$

$\rho_l = 961 \ kg/m^3$

$\nu_l = 0.293 \times 10^{-6} \ m^2/s.$

$Pr_l = 1.740$

$C_{pl} = 4216 \ J/kg\text{-}k$

$k_l = 0.68804 \ w/m\text{-}k$

$\mu_l = \rho_l \times \nu_l$

$\mu_l = 961 \times 0.293 \times 10^{-6}$

$\mu_l = 2.81 \times 10^{-4} \frac{N \cdot s}{m^2}$

from steam table for $T_{sat} = 100°C$.

$h_{fg} = 2256.9$ kJ/kg.

$= 2256.9 \times 10^3$ J/kg.

$v_g = 1.6720$ m³/kg.

To find ρ_v

$\rho_v = 1/v_g$

$\rho_v = 1/1.6720$

$\rho_v = 0.5977$ kg/m³.

To find ΔT

$\Delta T = T_w - T_{sat}$

$\Delta T = 115 - 100$

$\Delta T = 15°C$.

$\Delta T < 50°C$.

So, This is nucleate boiling.

) Power required to boil the water (Q)

$$\frac{Q}{A} = \mu_l h_{fg} \left[g \frac{(\rho_l - \rho_v)}{\sigma} \right]^{0.5} \left[\frac{C_{pl} \Delta T}{C_{sf} h_{fg} Pr^n} \right]^3$$

$\sigma = 0.0588$ $\quad C_{sf} = 0.013$ $\quad n = 1$

$A = \pi/4\, d^2 = \pi/4\, (0.38)^2 = 0.1134\, m^2.$

$$\frac{Q}{0.1124} = 281 \times 10^{-4} \times 2256.9 \times 10^3 \times 9.81 \left[\frac{(961 - 0.5977)}{0.0588}\right]^{0.5} \left[\frac{4216 \times 15}{0.015 \times 2256.9 \times 10^3 \times 1.740}\right]^3$$

$$= 634.1889 \left[\frac{9421.54}{0.0588}\right]^{0.5} \left[\frac{63240}{51051}\right]^3$$

$$= 634.1889\, (400.28)(1.90)\, (0.1134)$$

$$Q = 54.7 \times 10^3\, W$$

2. Rate of evaporation (m)

$$Q = m \times h_{fg}$$

$$54.7 \times 10^3 = m \times 2256.9 \times 10^3$$

$$m = 0.024\ kg/s.$$

3. critical flux

$$Q/A = 0.18\, h_{fg}\, \rho_v \left[\frac{\sigma g (\rho_l - \rho_v)}{\rho_v^2}\right]^{0.25}$$

$$Q/A = 0.18 \times 2256.9 \times 10^3 \times 0.5977 \times \left[\frac{0.0588 \times 9.81 \times (961 - 0.5977)}{(0.5977)^2}\right]^{0.25}$$

$$= 242810.8 \left[\frac{0.57 \quad (960.4)}{0.35} \right]^{0.25}$$

$$= 242810.8 \left[\frac{547.428}{0.35} \right]^{0.25}$$

$$= 242810.8 (1564.08)^{0.25}$$

$$Q/A = 1.52 \times 10^{6} \ W/m^2.$$

13.A) Given,

Surface Temperature $T = 3000K$

Solution.

1. Monochromatic emissive power.

from planck's distribution law,

$$E_{b\lambda} = \frac{C_1 \lambda^{-5}}{e^{\left(\frac{C_2}{\lambda T}\right)} - 1}$$

from HMT databook, pg. 71

where.

$C_1 = 0.374 \times 10^{-15} \ Wm^2$

$C_2 = 14.4 \times 10^{-3} \ mK$

$\lambda = 1 \times 10^{-6} m.$

$$E_{b\lambda} = \frac{0.374 \times 10^{-15} \quad (1 \times 10^{-6})^{-5}}{\left[\dfrac{144 \times 10^{-3}}{1 \times 10^{-6} \times 3000}\right] - 1}$$

$$E_{b\lambda} = 3.10 \times 10^{12} \ W/m^2.$$

Maximum wave length (λ_{max}):
from Wien's law,

$$\lambda_{max} T = 2.9 \times 10^{-3} \ mK$$

$$\lambda_{max} = \frac{2.9 \times 10^{-3}}{3000}$$

$$\lambda_{max} = 0.966 \times 10^{-6} m$$

Maximum emissive power $(E_{b\lambda})_{max}$:

$$(E_{b\lambda})_{max} = 1.307 \times 10^{-5} \ T^5$$

$$= 1.307 \times 10^{-5} \times (3000)^5$$

$$(E_{b\lambda})_{max} = 3.17 \times 10^{12} \ W/m^2.$$

Total emissive power (E_b):
from Stefan-Boltzmann law,

$$E_b = \sigma T^4$$

from HMTDB. 71

where,

σ = Stefan - Boltzmann constant

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

$E_b = (5.67 \times 10^{-8})(3000)^4$

$E_b = 4.59 \times 10^{6}\ W/m^2$

5. Total emissive power of real surfaces

$$(E_b)_{real} = \varepsilon \sigma T^4$$

where,

ε = emissivity $= 0.85$

$(E_b)_{real} = 0.85 \times 5.67 \times 10^{-8} \times (3000)^4$

$(E_b)_{real} = 3.90 \times 10^{6}\ W/m^2$.

Part - C.

A) Given :

$T_1 = 900K$

$T_2 = 500K$

$A = 6m^2$

To find :

(i) $(Q_{12})_{net}$ both plates are black $\epsilon = 1$

(ii) $(Q_{12})_{net}$ plates have an emissivity of $\epsilon = 0.5$

Solution:

case (i) $\epsilon_1 = \epsilon_2 = 1$

$$(Q_{12})_{net} = \frac{A\sigma (T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

$$(Q_{12})_{net} = \frac{A \times 5.67 \left[(T_1/100)^4 - (T_2/100)^4\right]}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

$$(Q_{12})_{net} = \frac{6 \times 5.67 \left[(900/100)^4 - (500/100)^4\right]}{\frac{1}{1} + \frac{1}{1} - 1}$$

$$(Q_{12})_{net} = 201.9 \times 10^3 W.$$

case (ii) $\epsilon_1 = \epsilon_2 = 0.5$

$$(Q_{12})_{net} = \frac{A\sigma (T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

$$(Q_{12})_{net} = \frac{6 \times 5.67 \left((900/100)^4 - (500/100)^4\right]}{\frac{1}{0.5} + \frac{1}{0.5} - 1}$$

$(\dot{Q}_{12})_{net} = 67\,300 W.$