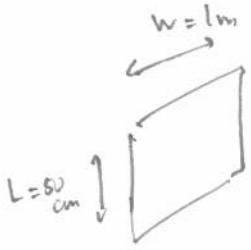
Quiz V

This is a 50 minute closed-book exam; no notes. Please put your name on the top sheet. Answer all three questions. Explain your working and state any assumptions you have made.

1 (3 points) Circle the correct answer.

1. The Grashof number
   - is independent of fluid properties.
   - (•) is a Reynolds number for free convection.
   - is the same as the Rayleigh number.
   - is always greater than 1.
   - is proportional to h, the heat transfer coefficient.
2. A gray body
   - is the same as a black body.
   - does not emit radiation.
   - is perfectly reflective.
   - does not obey Planck's law.
   - (•) has frequency-independent absorptivity.
3. View factors
   - are greater than 1.
   - depend on the Stefan–Boltzmann law.
   - are independent of the shape of objects.
   - can only be found by numerical calculation.
   - (•) are purely geometrical.

2 (7 points) A radiator may be viewed as a one-sided vertical plane with width 1 m^2 and height 50 cm. If the ambient air is at 20°C and the radiator is at 40°C, calculate the heat flux out of the radiator. What happens if you repeat the calculation with the radiator immersed in water?



$T_f = 30°C \rightarrow$ $\gamma = 1.5 \times 10^8 \ m^{-3} K^{-1}$ air

$Pr = 0.7$

$k = 2.6 \times 10^{-2} \ W m^{-1} K^{-1}$

$Ra = \gamma L^3 \Delta T Pr = 1.5 \times 10^8 \times 0.5^3 \times 20 \times 0.7 = 2.6 \times 10^8$

$Nu = C Ra^n = 0.58 \ [2.6 \times 10^8]^{0.25} = 73.8$

$Q = h A \Delta T = \frac{k Nu}{L} W \Delta T = 38.3 \ W$

Water : $\gamma = 3.5 \times 10^9 \ m^{-3} K^{-1}$, $Pr = 5.5$, $k = 0.6 \ \frac{W}{mK}$

$Ra = 4.8 \times 10^{10}$, $Nu = 271.7$, $Q = 3.26 \ kW$

Much bigger

3 (10 points) A back horizontal disk with a diameter of 1 m, in contact with the ground, is being heated by solar radiation ($q = 1000$ W/m^2). Heat is lost to the surrounding air at 25°C by natural convection. There is no forced convection. The surface opposite the sun is insulated from the boundary. Find the surface temperature. [$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}.]

Energy balance : $q_{solar} = \sigma T_s^4 + h(T_s - T_a)$

Horizontal disk : $L = 0.9$ m

$T_a (= 300K) = 298K$

No convection : $T_s = 364K = 91°C$

Guess $T_s = 350K$ $\Rightarrow$ $T_f = 325K = 52°C$

$\gamma = 10^8$ m^{-3} K^{-1}, $Pr = 0.7$, $k = 2.8 \times 10^{-2}$ W m^{-1} K^{-1}

$Ra = 2.6 \times 10^9$, $Nu = 193.2$, $h\Delta T = 312$

$\Rightarrow n = 0.33$, $C = 0.15$ $\Rightarrow$ $T_s = \left(\frac{1000 - h\Delta T}{\sigma}\right)^{0.25} = 332$ K

Try $T_s = 340K$ $\Rightarrow$ $T_f = 320K = 47°C$

γ, Pr, k basically same

$Ra = 2.1 \times 10^9$, $Nu = 180.0$, $h\Delta T = 235$ $\rightarrow$ $T_s = 341K$

Good enough $T_s = 340K \triangleq 67°C$