**CANKAYA UNIVERSITY**
**FACULTY OF ENGINEERING**
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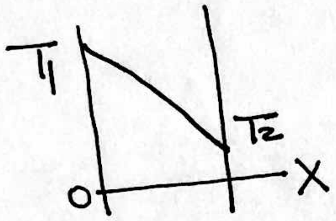
**ME 313 HEAT TRANSFER**

**Fall 2016**

**HW 1** SOLUTIONS

1) Determine the flux q and the heat transfer rate across an iron plate with area A = 0.5 $m^2$ and thickness L = 0.02 m [k = 70 W / (m. °C)] when one of its surfaces is maintained at $T_1$ = 60 °C and the other at $T_1$ = 20 °C.

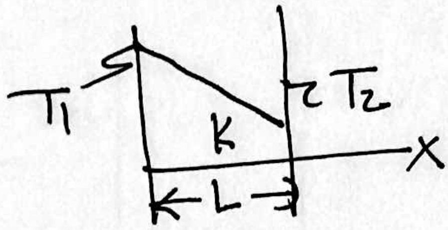



L = 0.02 m
k = 70 W/m°C
A = 0.5 $m^2$
$T_1$ = 60°C
$T_2$ = 20°C

$$q'' = \frac{k(T_1 - T_2)}{L} = \frac{(70 W/m^2°C)(60-20)}{0.02} = 140 \text{ kW/m}^2$$

$$q = q''A = \left(140 \frac{kW}{m^2}\right)(0.5 m^2) = 70 kW$$

**2)** The heat flow rate through a wood board L = 2 cm thick for a temperature difference of ΔT = 25 °C between the two surfaces is 150 W / m². Calculate the thermal conductivity of the wood.




$L = 2cm$

$\Delta T = T_1 - T_2 = 25\,°C$

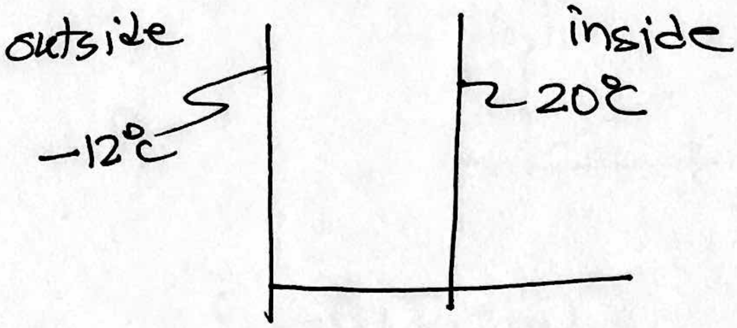
$q'' = 150\ W/m^2$

$$q'' = \frac{k\Delta T}{L} = \frac{k(T_1 - T_2)}{L}$$

$$150\ \frac{W}{m^2} = k\left(\frac{W}{m\,°C}\right)\left(\frac{25\,°C}{0.02m}\right)$$

$$k = 0.12\ W/m\,°C$$

3) The inside and outside surface temperatures of a window glass are 20 and – 12 °C, respectively. If the glass is 80 cm by 40 cm, is 1.6 cm thick and has thermal conductivity 0.78 W / (m. °C), determine the heat loss through the glass over 3 h.




$k = 0.78 \frac{W}{m°C}$

$L = 1.6 cm = 0.016 m$

$A = (0.8)(0.4)$
$= 0.32 m^2$

$$q = \frac{KA\Delta T}{L}$$

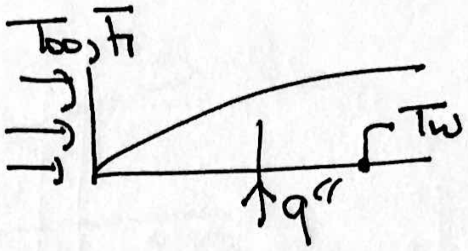
$$= \frac{(0.78 \frac{W}{m°C})(0.32 m^2)(20-(-12))°C}{0.016m} = 499.2 W$$

$$= (499.2 \frac{J}{s})(\frac{3600 s}{hr})(3 hr) = 5\,391\,360 J$$

$$= 5\,391.36 kJ$$

4) An electrically heated plate dissipates heat by convection at a rate of q = 8000 W / m² into the ambient air $T_f$ = 25 °C. If the surface of the hot plate is at $T_w$ = 125 °C, calculate the heat transfer coefficient for convection between the plate and the air.

q

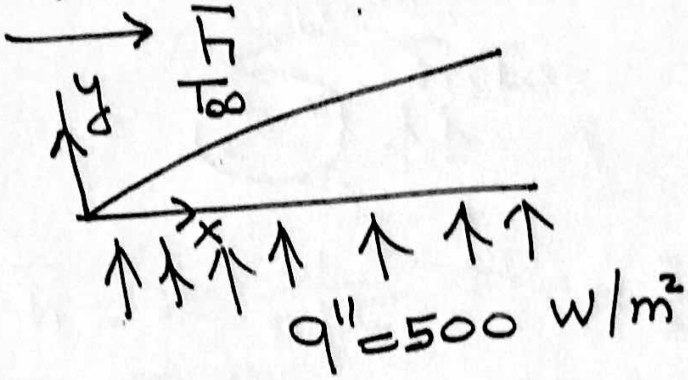



$q'' = \bar{h}(T_w - T_\infty)$

$8000 \frac{W}{m^2} = \bar{h}\,(125-25)\,°C$

$\bar{h} = 80\ W/m^2\,°C$

6) Heat is supplied to a plate from its back surface at a rate of 500 $W / m^2$ and is removed from its front surface by air flow at 30 °C. If the heat transfer coefficient between the air and the plate surface is h = 20 W / ($m^2$. °C), what is the temperature of the front surface of the plate?




$\bar{h} = 20 \frac{W}{m^2 °C}$

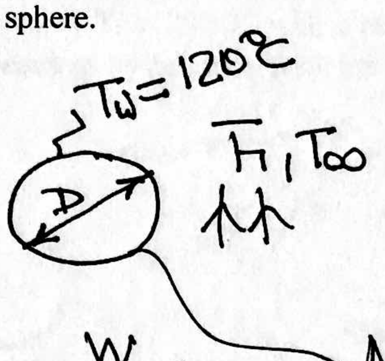
$T_\infty = 30°C$

$q'' = \bar{h}(T_w - T_\infty)$

$500 \frac{W}{m^2} = (20 \frac{W}{m^2 °C})(T_w - 30)°C$

$T_w = 55°C$

5) A 25 cm diameter sphere at 120 °C is suspended in air at 20 °C. If the natural convection heat transfer between the sphere and the air is 15 W / (m². °C), determine the rate of heat loss from the sphere.




$\bar{h} = 15 \frac{W}{m^2 °C}$ $\quad A = \frac{\pi}{4} D^2$

$D = 25 °C$

$T_\infty = 20 °C$

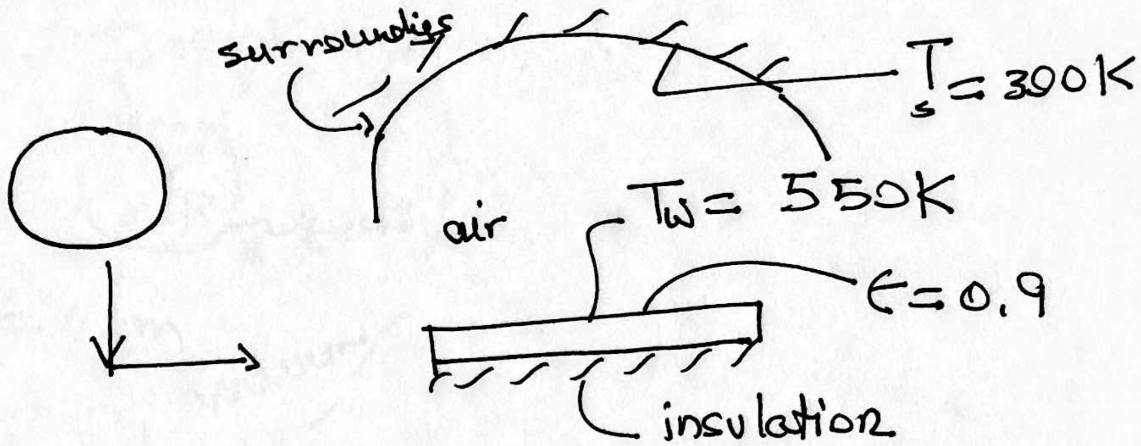
$q = \bar{h} A (T_w - T_\infty)$

$= (15 \frac{W}{m^2 °C})(\pi)(0.25 m)^2 (120 - 20) °C$

$\cong 294\ W$

$= 73\ W$

7) A heated plate of D = 0.2 m diameter has one of its surfaces insulated, and the other is maintained at $T_w$ = 550 K. If the hot surface has an emissivity $\varepsilon_w$ = 0.9 and is exposed to a surrounding area at $T_s$ = 300 K with atmospheric air being the intervening medium, calculate the heat loss by radiation from the hot plate to the surroundings.




1) air is not participating

$q = A \epsilon \sigma (T_w^4 - T_s^4)$

$A = \frac{\pi}{4}(0.2)^2 \simeq 0.0314\ m^2$ (0.1256 $W$)

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

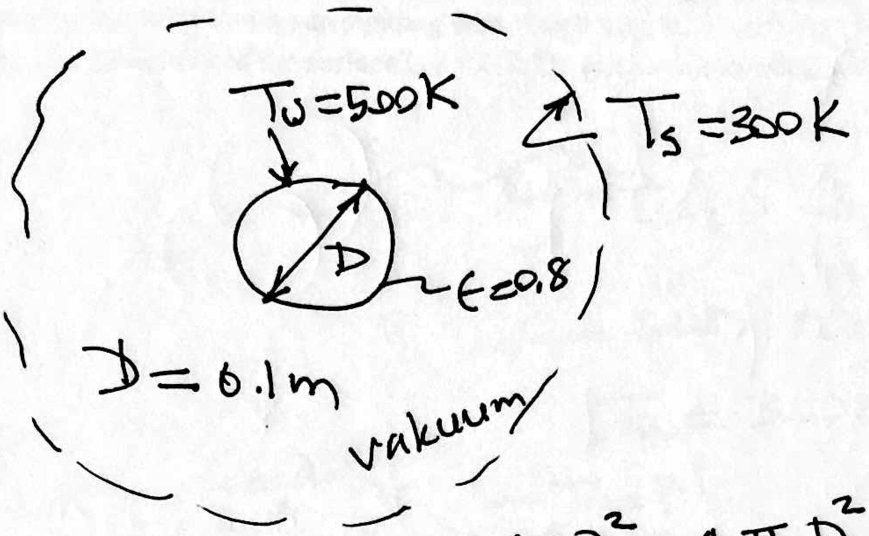
$T_w = 550\ K \qquad T_s = 300\ K$

$q = (0.0314)(0.9)(5.67 \times 10^{-8})(550^4 - 300^4)$ (0.1256 $m^2$)

$= 134.5\ W$

$534.58\ W$

8) A sphere 10 cm in diameter is suspended inside a large evacuated chamber whose walls are kept at 300 K. If the surface of the sphere has emissivity ε = 0.8 and is maintained at 500 K, determine the rate of heat loss from the sphere to the walls of the chamber.



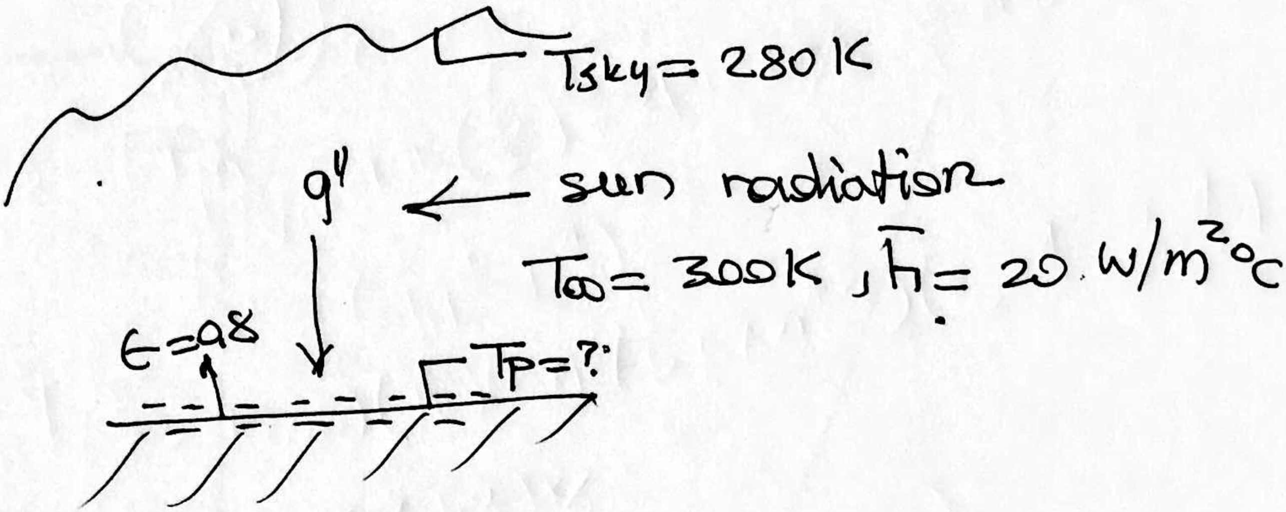

$$A = 4\pi r^2 = 4\pi \left(\frac{D}{2}\right)^2 = 4\pi D^2/4 = \pi D^2$$

$$q = \epsilon A \sigma (T_w^4 - T_s^4)$$

$$= (0.8)(\pi)(0.1)^2(5.67\times10^{-8})(500^4 - 300^4)$$

$$= 77.52\ W$$

**9)** A small, thin metal plate of area A m² is kept insulated on one side and exposed to the sun on the other side. The plate absorbs solar energy at a rate of 500 W / m² and dissipates it by convection into the ambient air at $T_\infty = 300$ K with a convection heat transfer coefficient $h_c = 20$ W / (m². °C) and by radiation into a surrounding area which may be assumed to be a blackbody at $T_{sky} = 280$ K. The emissivity of the surface is $\varepsilon = 0.9$. Determine the equilibrium temperature of the plate.




500 W/m² absorbed

$q''_c =$

$$500\ \frac{W}{m^2} = 20\,(T_p - 300) + (0.9)(5.67\times10^{-8})\left[T_p^4 - (280)^4\right]$$

Solve using Matlab fzero command

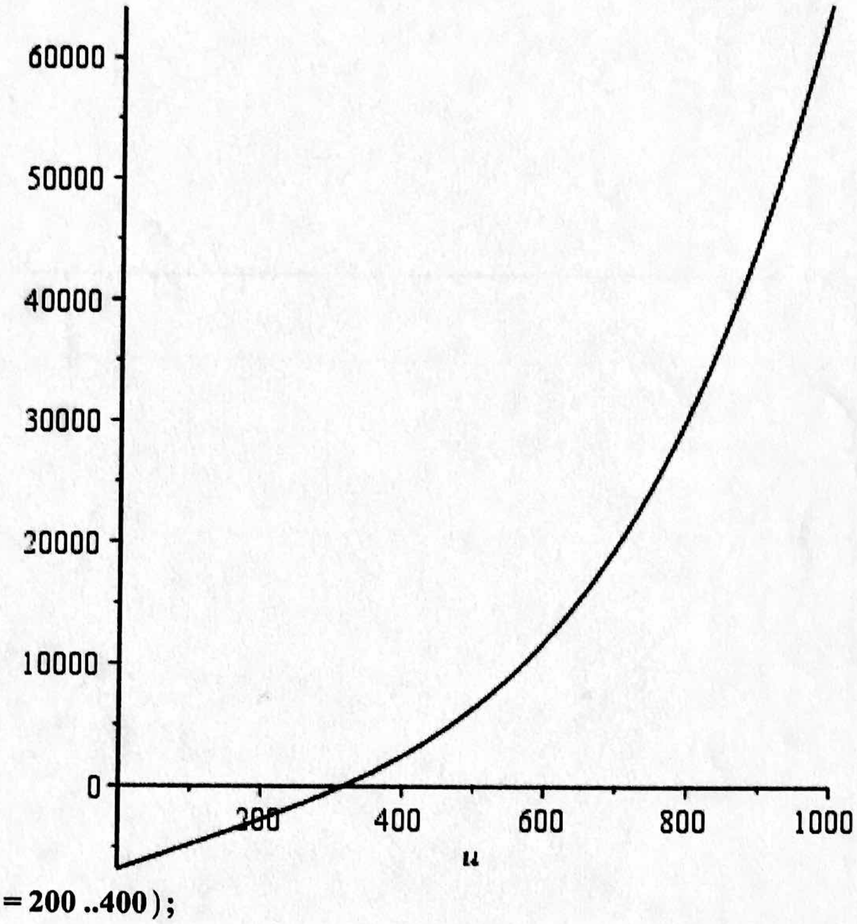
or Use Maple 2016

see next page

```
> restart;
>
> # let plate temperature be u
> eq := -500 + 20(u - 300) + (0.9)·(5.67·10^-8)·(u^4 - 280^4);
```

$$eq := -6813.658957 + 20\,u + 5.103000000\,10^{-8}\,u^4$$

```
> with(plots) :
>
> plot(eq, u = 0 ..1000);
```

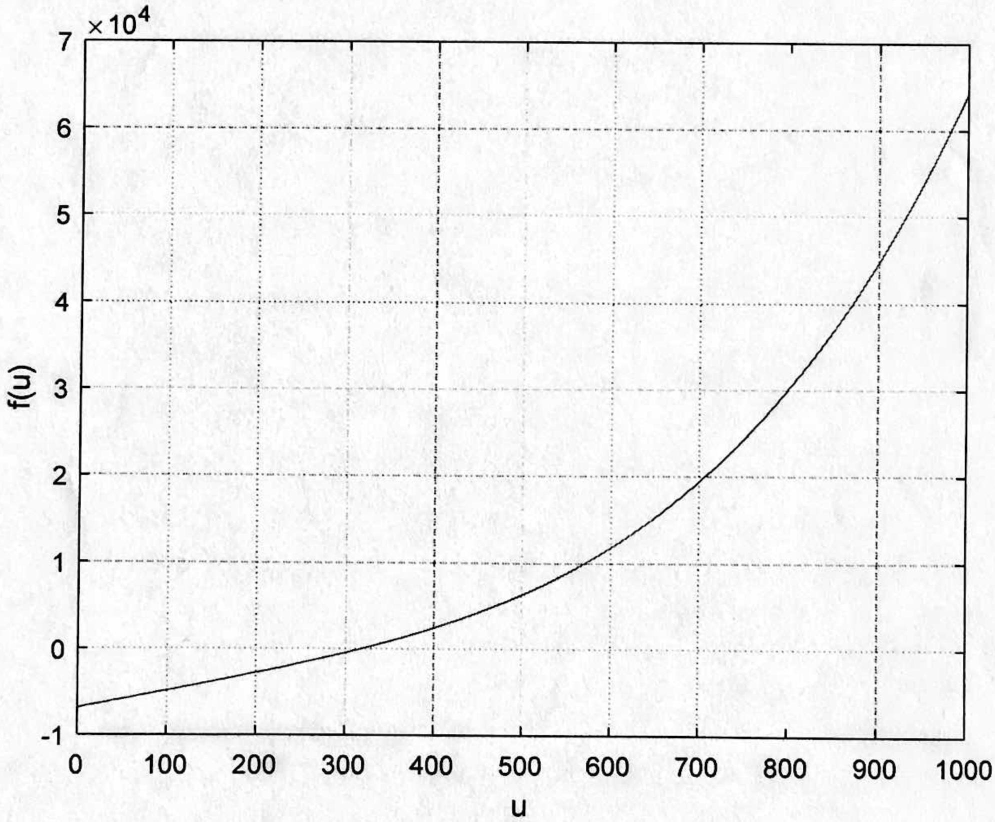



```
> fsolve(eq, u = 200 ..400);
```

315.4257948

```
>
```

```
>> f=@(u)-500+20*(u-300)+(0.9)*(5.67e-8)*(u.^4-280^4)

f =

   @(u)-500+20*(u-300)+(0.9)*(5.67e-8)*(u.^4-280^4)

>> u=0:10:1000;

% evaluate function f(u)

>> F=f(u);

>> plot(u,F)

>> grid

>> xlabel('u')

>> ylabel('f(u)')
```




```
>> fzero(f,300)

ans =

  315.4258
```