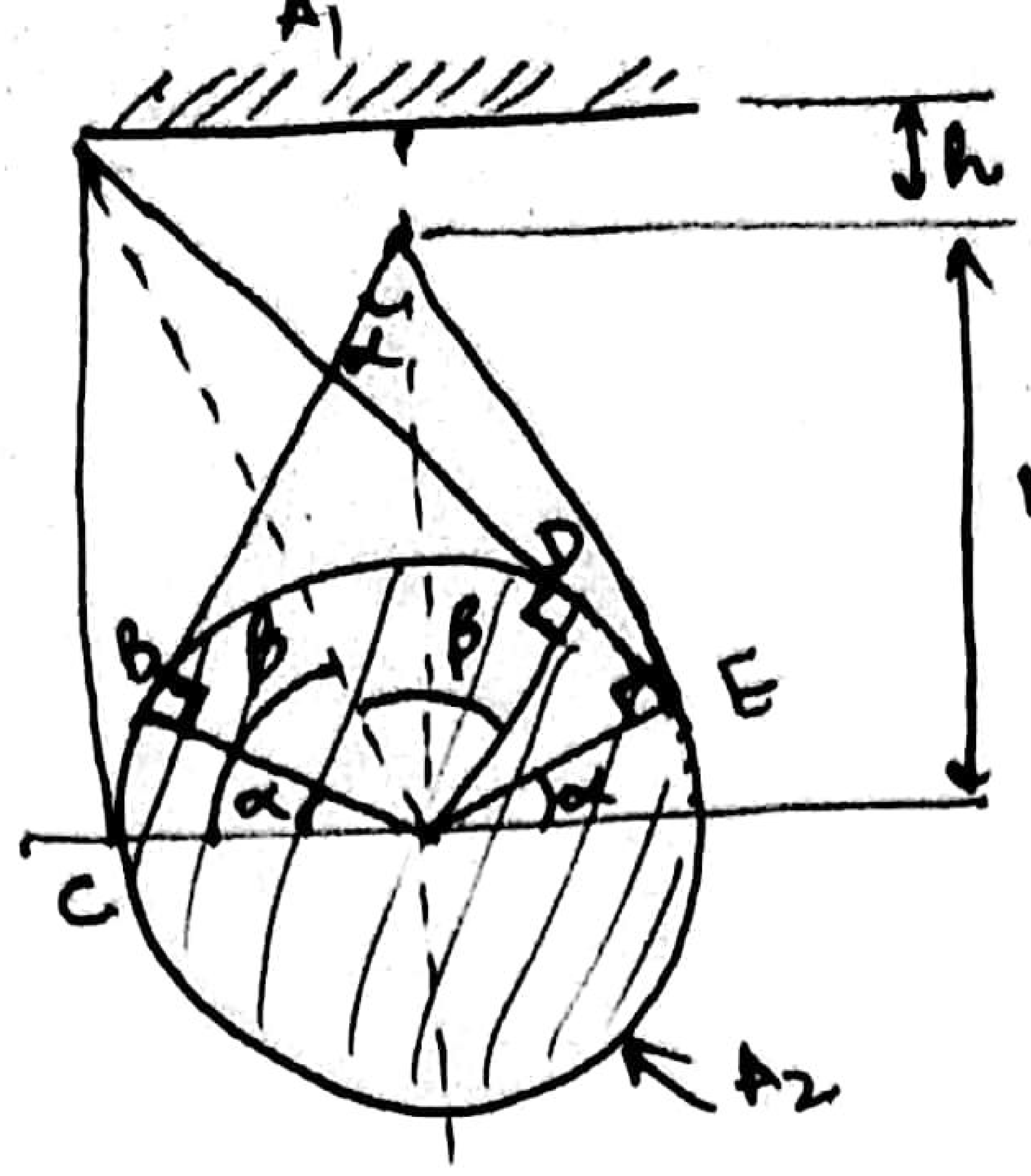
Q 1



Determine the view factor F_{1-2} for the configuration shown in fig

Fig 4.18
Example 4.12

Q2 Consider a very long duct as shown in fig 5.2. The duct is 30 cm x 40 cm in cross-section, and all surfaces are black. The top & bottom walls are at temperature $T_1 = 1000K$ while the side walls at temperature $T_2 = 600K$. Determine the net radiative heat transfer rate (per unit duct length)

Also draw the radiation network diagram

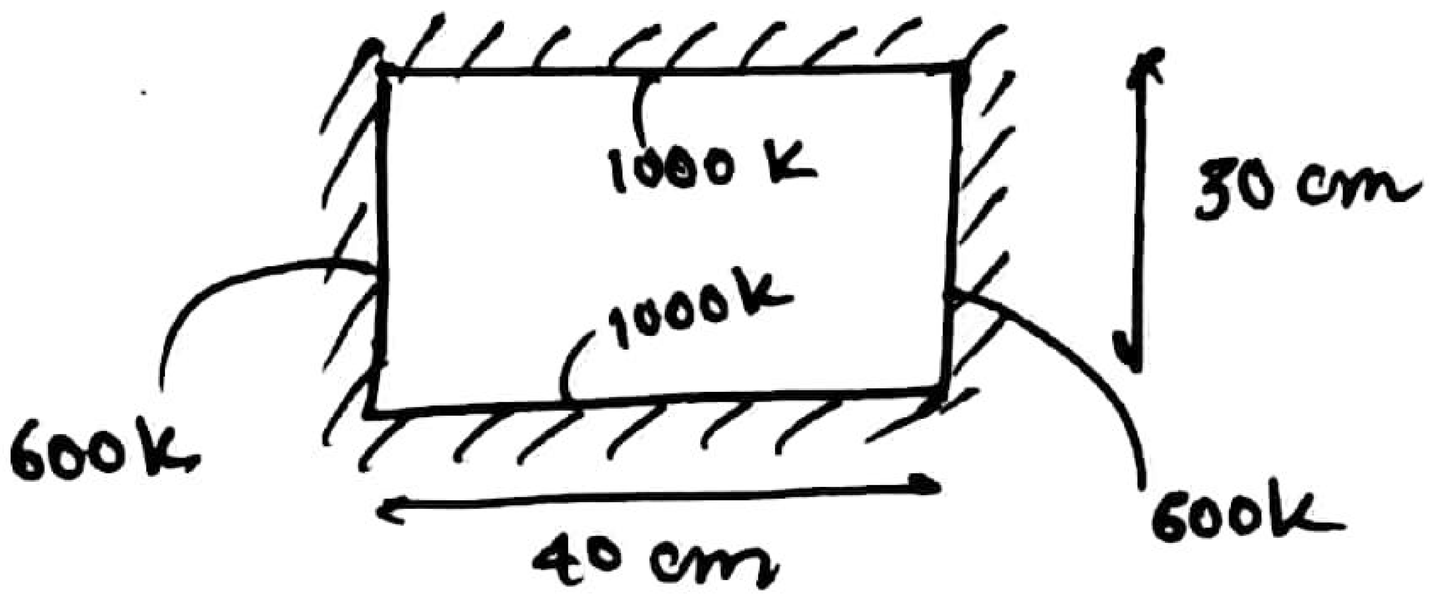
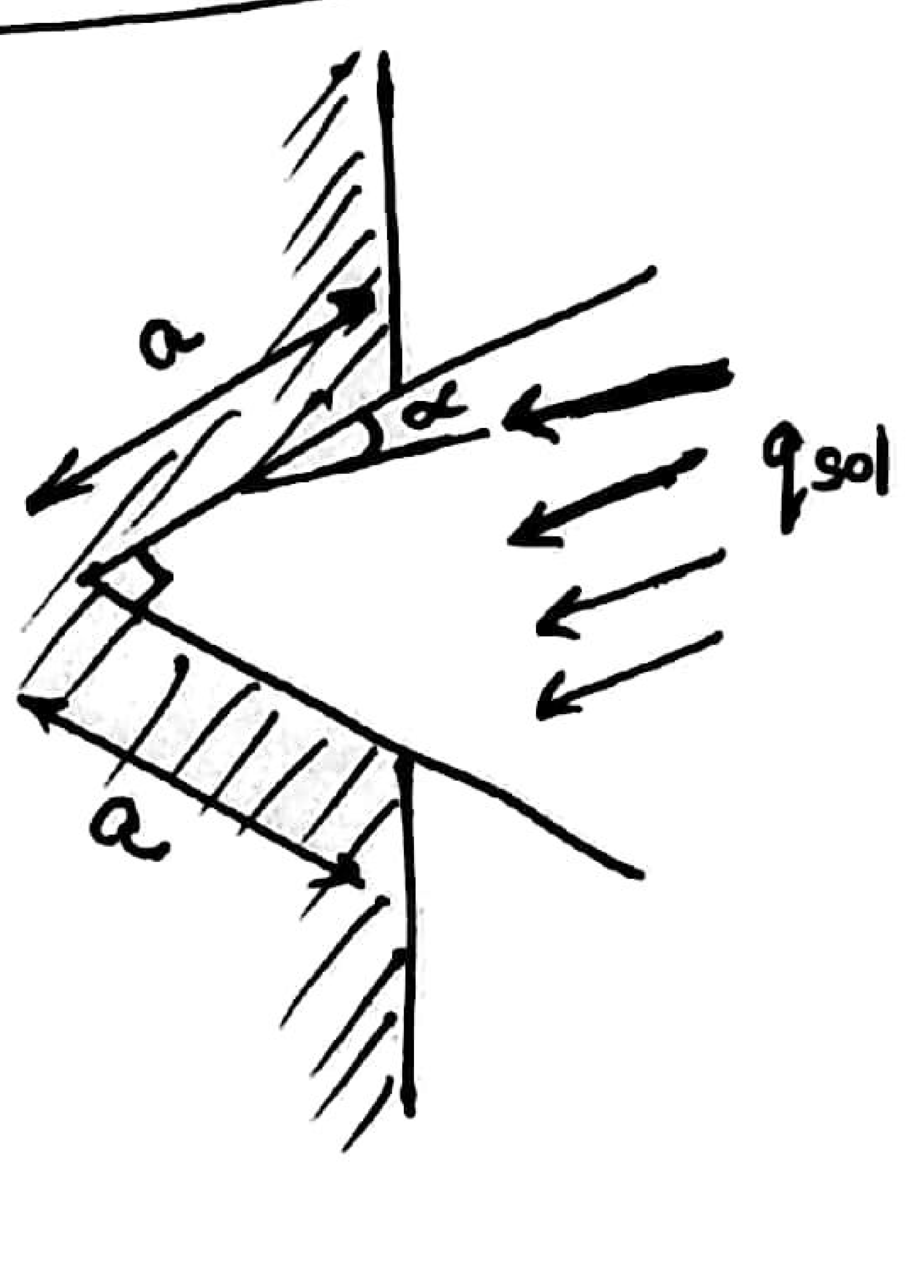


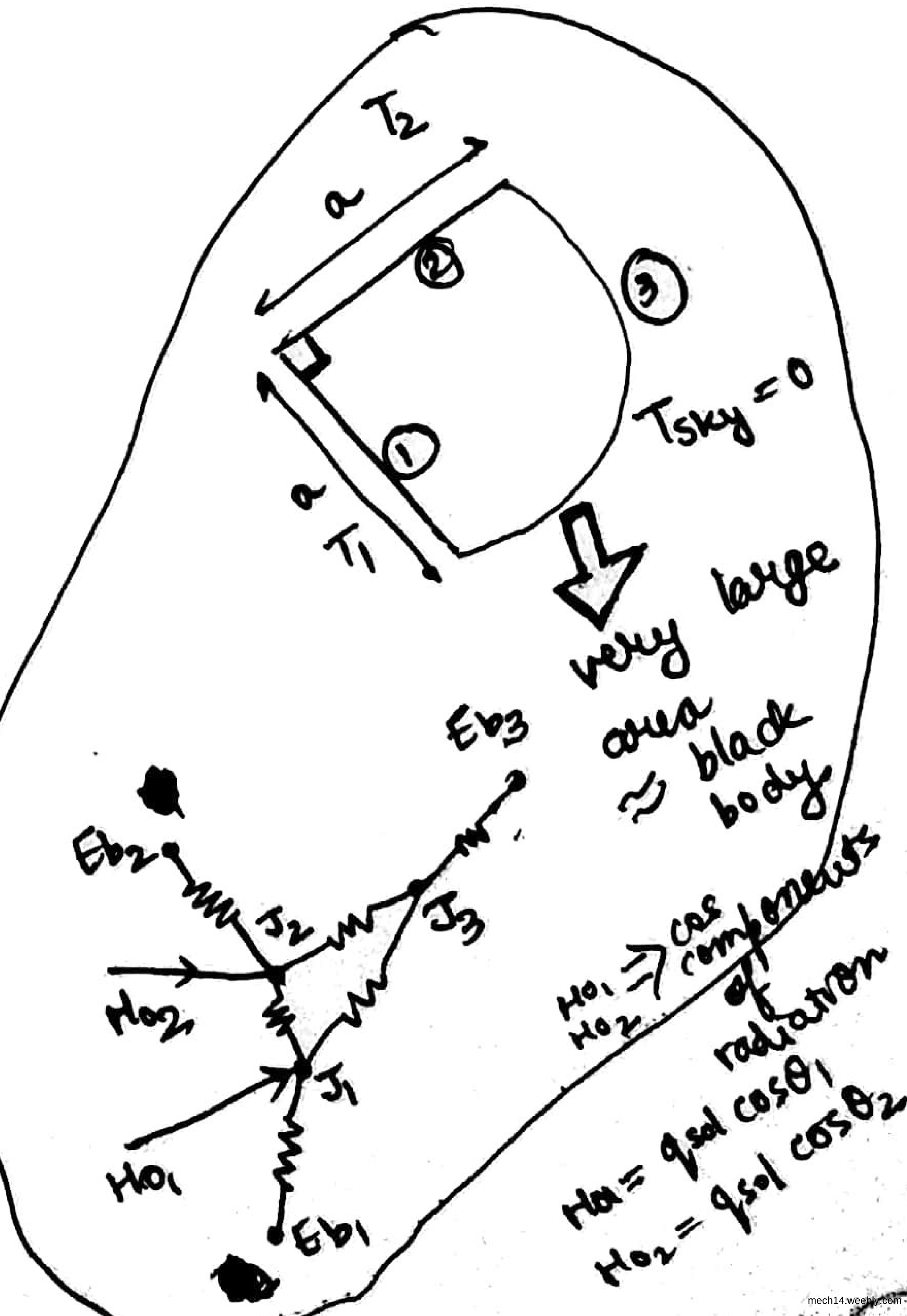
Fig 5.2
Example 5.1

Q3 A right-angled groove, consisting of two long black surfaces of width a, is exposed to solar radiation q_{sol}. The entire groove surface is kept isothermal at temperature T. Determine the net radiative heat transfer rate from the groove.

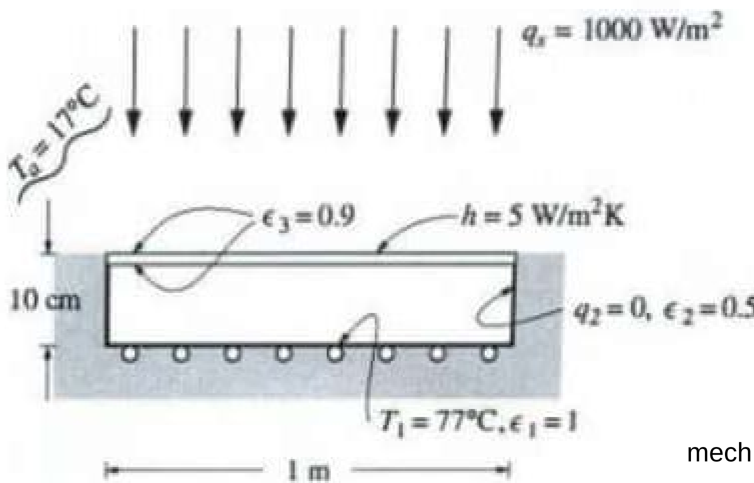
Also draw the radiation network diagram

Fig 5.4
Example 5.3

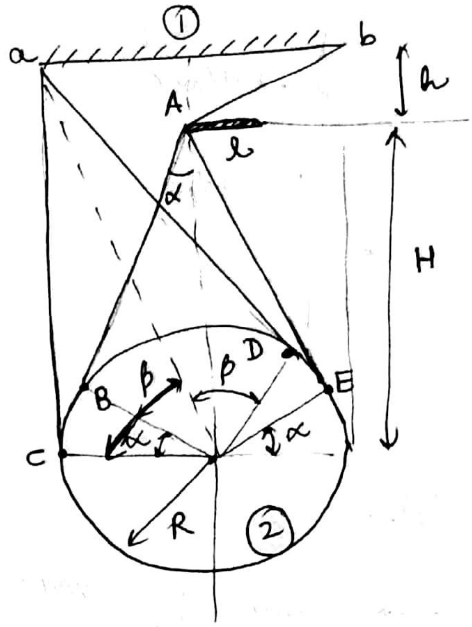




Example 5.8. Consider a solar collector shown in Fig. 5-12*a*. The collector consists of a glass cover plate, a collector plate, and side walls. We shall assume that the glass is totally transparent to solar irradiation, which penetrates through the glass and hits the absorber plate with a strength of 1000 W/m^2. The absorber plate is black and is kept at a constant temperature $T_1 = 77°C$ by heating water flowing underneath it. The side walls are insulated and made of a material with emittance $\epsilon_2 = 0.5$. The glass cover may be considered opaque to thermal (i.e., infrared) radiation with an emittance $\epsilon_3 = 0.9$. The collector is 1 m × 1 m × 10 cm in dimension and is reasonably evacuated to suppress free convection between absorber plate and glass cover. The convective heat transfer coefficient at the top of the glass cover is known to be $h = 5.0$ W/m^2 K, and the temperature of the ambient is $T_a = 17°C$. Estimate the collected energy for normal solar incidence.



Q1



$$F_{12} = F_{12\,left} + F_{12\,right}$$

for $F_{12\,left}$, $F_{12\,left} = \dfrac{\cancel{aD} + DE + \cancel{Ab} + \cancel{AB} + BC - (\cancel{aC} + \cancel{Ab} + \cancel{AE})}{2\,ab}$

$$= \frac{DE + BC}{2ab}$$

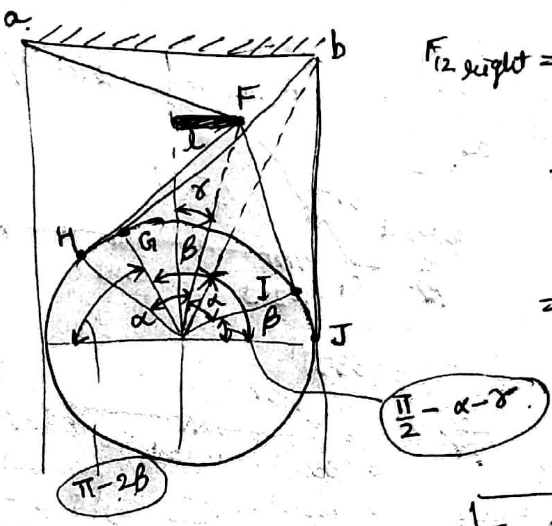
$$= \frac{(\pi - \cancel{\alpha} - 2\beta)R + \cancel{\alpha}R}{2R \times 2}$$

$$= \frac{\pi}{4} - \frac{\beta}{2}$$

we have, $\tan\left(\frac{\pi}{2} - \beta\right) = \dfrac{R}{H+h}$

$$\Rightarrow \beta = \frac{\pi}{2} - \tan^{-1}\frac{R}{H+h}$$

$$\therefore \boxed{F_{12\,left} = \frac{1}{2}\tan^{-1}\frac{R}{H+h}}$$



$$F_{12\,right} = \frac{\cancel{aF} + \cancel{FI} + IJ + \cancel{bG} + GH - (\cancel{bJ} + \cancel{aF} + \cancel{FH})}{2ab}$$

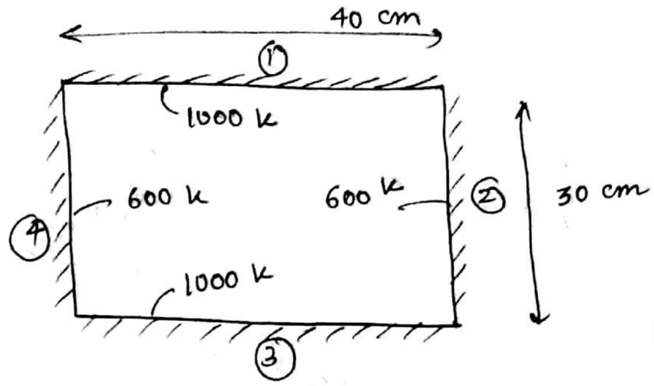
$$= \frac{IJ + GH}{2ab}$$

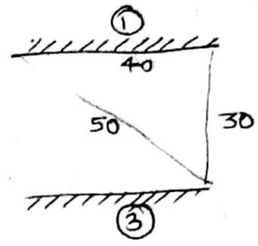
$$= \frac{\left(\frac{\pi}{2} - \alpha - \gamma\right)R + \left(\pi - 2\beta + \alpha - \frac{\pi}{2} - \gamma\right)R}{2 \times 2R}$$

$$= \frac{\pi}{4} - \frac{\beta}{2} - \frac{\gamma}{2} = \frac{1}{2}\left(\tan^{-1}\frac{R}{h+H} - \tan^{-1}\frac{l}{h}\right)$$

$$\therefore \boxed{F_{12} = F_{left} + F_{right} = \tan^{-1}\frac{R}{h+H} - \frac{1}{2}\tan^{-1}\frac{l}{h}}$$

Q2





$$F_{13} = \frac{(50+50)-(30+30)}{2 \times 40}$$

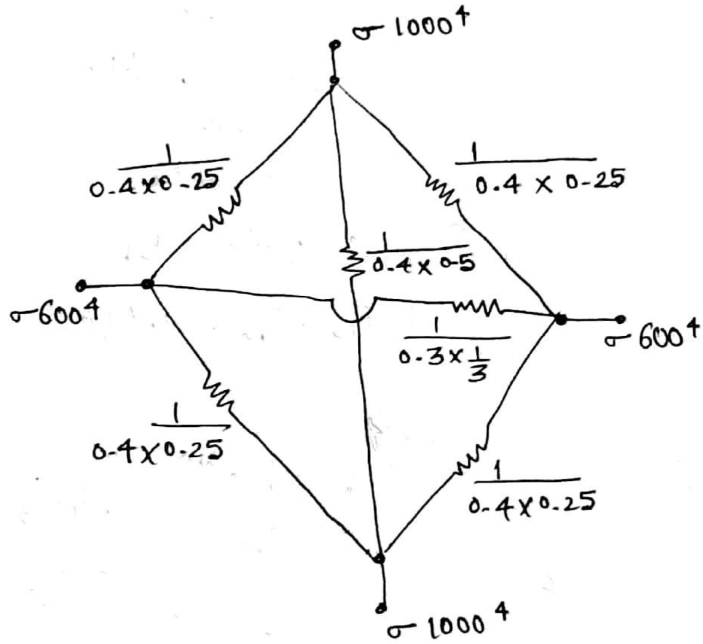
$$\boxed{F_{13} = 0.5 = F_{31}}$$

$$\boxed{\therefore F_{12} = F_{14} = 0.25}$$

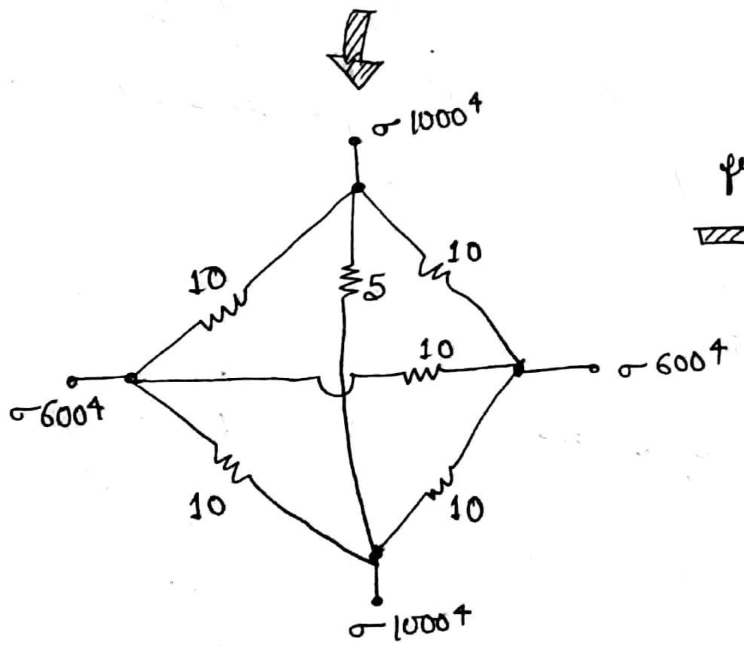
$$F_{12} \times 40 = F_{21} \times 30$$

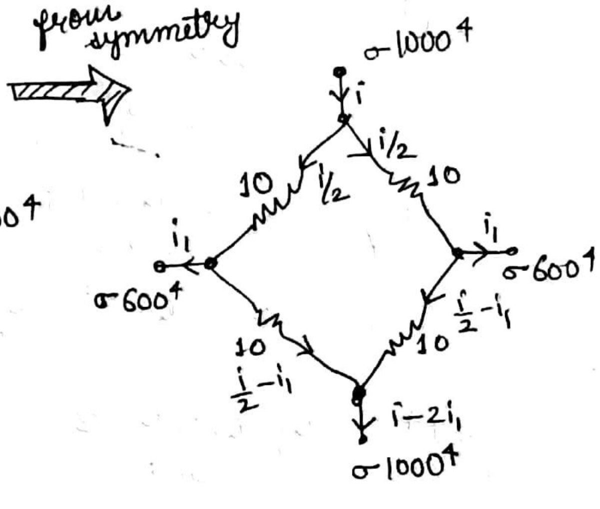
$$\Rightarrow \boxed{F_{21} = 1/3}$$

$$\boxed{\therefore F_{24} = 1/3}$$



All thermal resistances in m^{-2}





$$\sigma 1000^4 - 10\frac{i}{2} = \sigma 600^4$$

$$\Rightarrow \boxed{i = 9870.336 \ \frac{W}{m}}$$

$$\sigma 600^4 - 10\frac{i}{2} + 10 i_1 = \sigma 1000^4$$

$$\Rightarrow \boxed{i_1 = 9870.336 \ \frac{W}{m}}$$

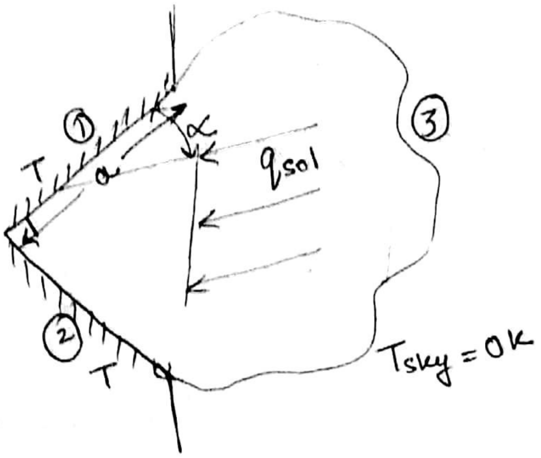
$\therefore$ $q_1 = 9870.336$ W/m

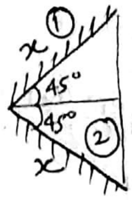
$q_2 = -9870.336$ W/m

$q_3 = 9870.336$ W/m

$q_4 = -9870.336$ W/m

3





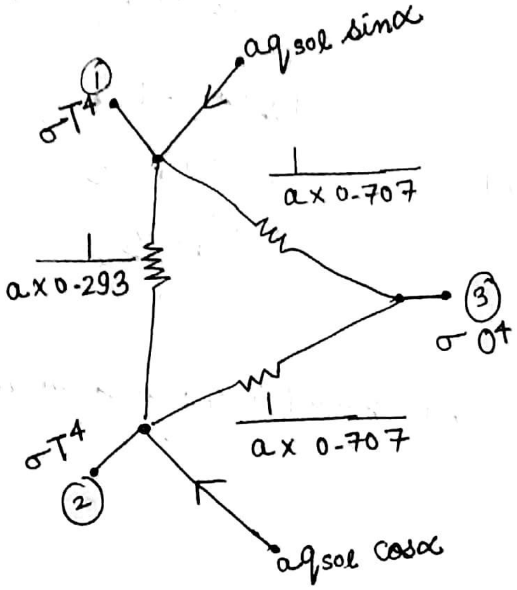
$$F_{12} = \frac{(x+x) - (0 + 2x \sin 45)}{2x}$$

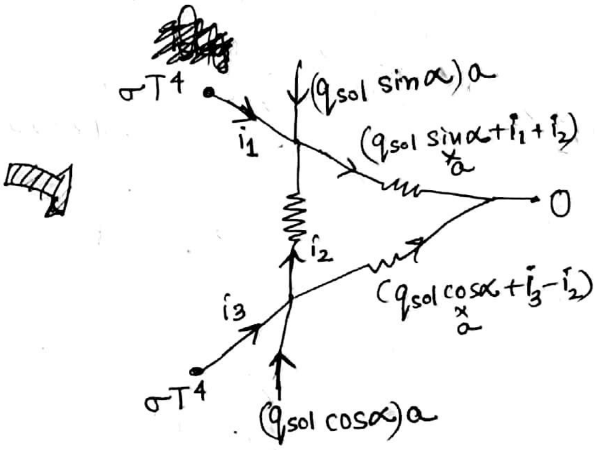
$$= \frac{2x - 2x \sin 45}{2x}$$

$$= 1 - \sin 45$$

$$= 0.293 = F_{21}$$

$$\therefore F_{13} = F_{23} = 0.707$$





$$\sigma T^4 + \frac{i_2}{0.293a} = \sigma T^4$$

$$\Rightarrow \boxed{i_2 = 0}$$

$$\sigma T^4 = \frac{a q_{sol} \sin\alpha + i_1}{0.707\, a}$$

$$\Rightarrow \boxed{i_1 = 0.707 a \sigma T^4 - a q_{sol} \sin\alpha}$$

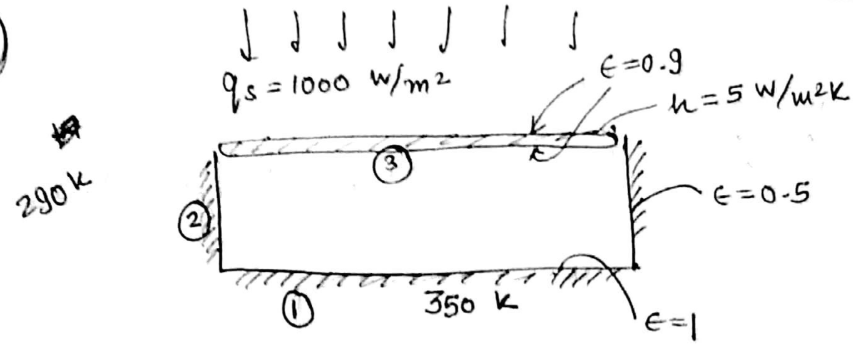
$$\sigma T^4 = \frac{a q_{sol} \cos\alpha + i_3}{0.707\, a}$$

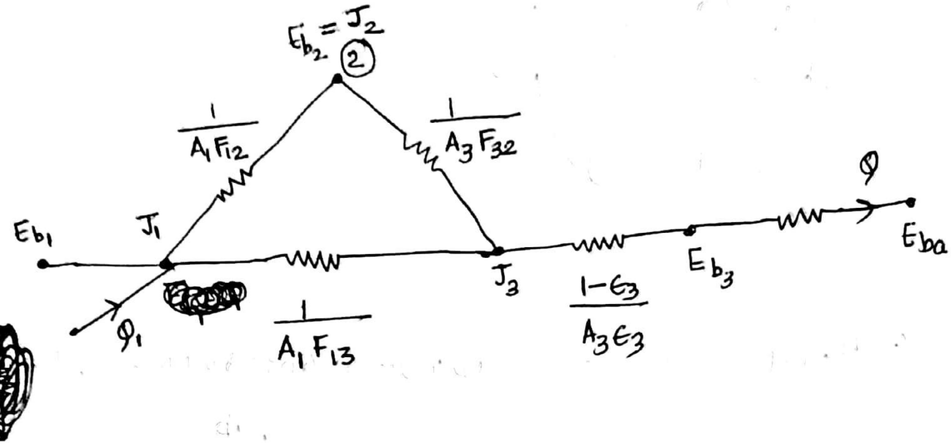
$$\Rightarrow \boxed{i_3 = 0.707 a \sigma T^4 - a q_{sol} \cos\alpha}$$

$\therefore$ Net heat transfer rate from the groove $= i_1 + i_3$

$$\boxed{q = 1.414 a \sigma T^4 - q_{sol} (\sin\alpha + \cos\alpha) a}$$

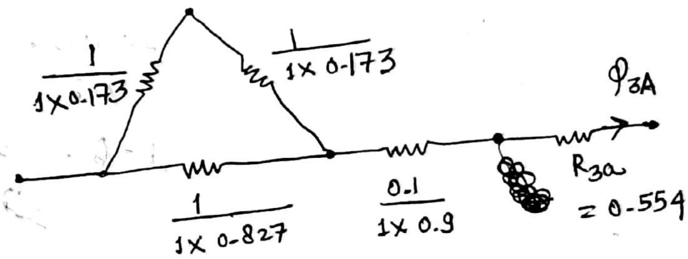
Q4





$F_{13} = 0.827$

$\therefore F_{12} = 0.173$



$A_1F_{12} = A_3F_{32}$

$$q_{3A} = \epsilon_3 A_3 \sigma(T_3^4 - T_a^4) + hA_3(T_3 - T_a)$$

$$= \sigma(T_3^4 - T_a^4)A_3\left[\epsilon_3 + \frac{h(T_3-T_a)}{\sigma(T_3^4-T_a^4)}\right]$$

$$= \frac{\sigma(T_3^4 - T_a^4)}{\frac{1}{A_3\left[\epsilon_3 + \frac{h(T_3-T_a)}{\sigma(T_3^4-T_a^4)}\right]}}$$

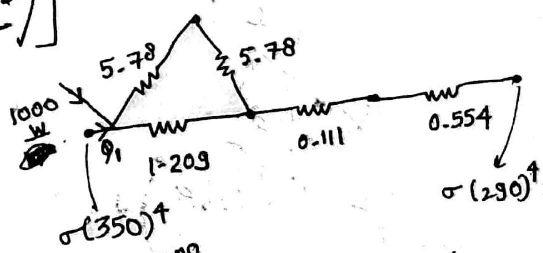
$$R_{3a} = \frac{1}{A_3\left[\epsilon_3 + \frac{h}{\sigma}\frac{T_3 - T_a}{T_3^4 - T_a^4}\right]}$$

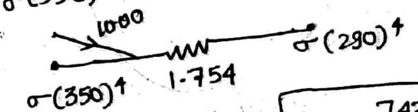
$$= \frac{1}{1\times\left[0.9 + \frac{5}{5.67\times 10^{-8}}\times\left(\frac{1}{4T_a^3}\right)\right]}$$

(Assuming $T_3 \approx T_a$)

$$= \frac{1}{1\times\left(0.9 + \frac{5}{4\sigma(290)^3}\right)}$$

$\Rightarrow \boxed{R_{3a} = 0.554\ m^{-2}}$





$$\therefore q_1 + 1000 = \frac{\sigma(350^4 - 290^4)}{1.754} \Rightarrow \boxed{q_1 = -743.54\,W}$$