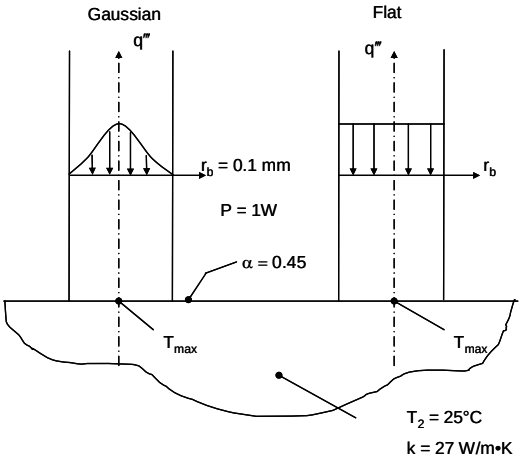
PROBLEM 4.18

KNOWN: Power, size and shape of laser beam. Material properties.

FIND: Maximum surface temperature for a Gaussian beam, maximum temperature for a flat beam, and average temperature for a flat beam.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Constant properties, (3) Semi-infinite medium, (4) Negligible heat loss from the top surface.

ANALYSIS: The shape factor is defined in Eq. 4.20 and is $q = Sk\Delta T_{1-2}$ (1)

From the problem statement and Section 4.3, the shape factors for the three cases are:

Beam Shape	Shape Factor	$T_{1,avg}$ or $T_{1,max}$
Gaussian	$2\sqrt{\pi}r_b$	$T_{1,max}$
Flat	πr_b	$T_{1,max}$
Flat	$3\pi^2 r_b/8$	$T_{1,avg}$

For the Gaussian beam, $S_1 = 2\sqrt{\pi} \times 0.1 \times 10^{-3}$ m $= 354 \times 10^{-6}$ m

For the flat beam (max. temperature), $S_2 = \pi \times 0.1 \times 10^{-3}$ m $= 314 \times 10^{-6}$ m

For the flat beam (avg. temperature), $S_3 = (3/8) \times \pi^2 \times 0.1 \times 10^{-3}$ m $= 370 \times 10^{-6}$ m

The temperature at the heated surface for the three cases is evaluated from Eq. (1) as

$$T_1 = T_2 + q/Sk = T_2 + P\alpha/Sk$$

For the Gaussian beam, $T_{1,max} = 25°C + 1\ W \times 0.45 / (354 \times 10^{-6}\ m \times 27\ W/m \cdot K) = 72.1°C$ <

For the flat beam (T_{max}), $T_{1,max} = 25°C + 1\ W \times 0.45 / (314 \times 10^{-6}\ m \times 27\ W/m \cdot K) = 78.1°C$ <

For the flat beam (T_{avg}), $T_{1,avg} = 25°C + 1\ W \times 0.45 / (370 \times 10^{-6}\ m \times 27\ W/m \cdot K) = 70.0°C$ <

COMMENTS: (1) The maximum temperature occurs at r = 0 for all cases. For the flat beam, the maximum temperature exceeds the average temperature by 78.1 – 70.0 = 8.1 degrees Celsius.