Machine Design Homework 2

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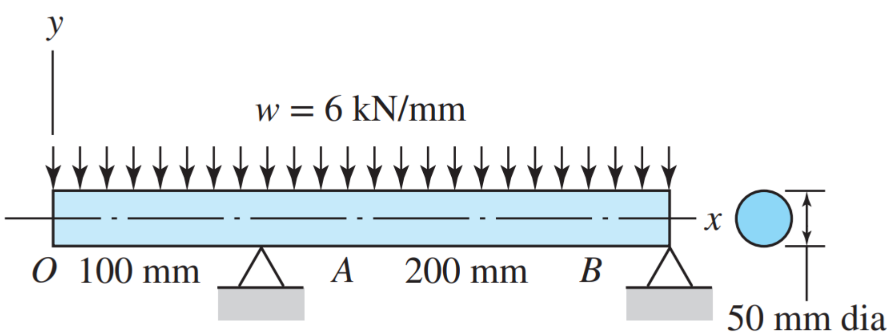
[1]:
```python
# Notebook Preamble
import sympy as sp
import numpy as np
import matplotlib.pyplot as plt
from IPython.display import display, Markdown

plt.style.use('maroon_ipynb.mplstyle')
```

Contents

1 Problem 3-39

1.1 Given

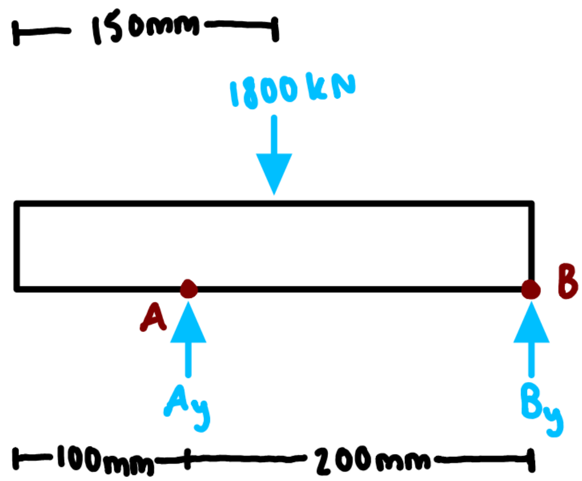


1.2 Find

For the beam above, find the maximum tensile stress due to M and the maximum shear stress due to V.

1.3 Solution

The free body diagram is,



[2]:
```
# Getting reaction forces
Ay, By = sp.symbols('A_y B_y')
eq1 = sp.Eq(Ay + By, 1800)
eq2 = sp.Eq(200*Ay, 150*1800)

sol = sp.solve([eq1, eq2], dict=True)[0]
[display(eq) for eq in [eq1, eq2]]
```

```python
display(Markdown('---'))

for key, value in sol.items():
    display(sp.Eq(key, value))
```

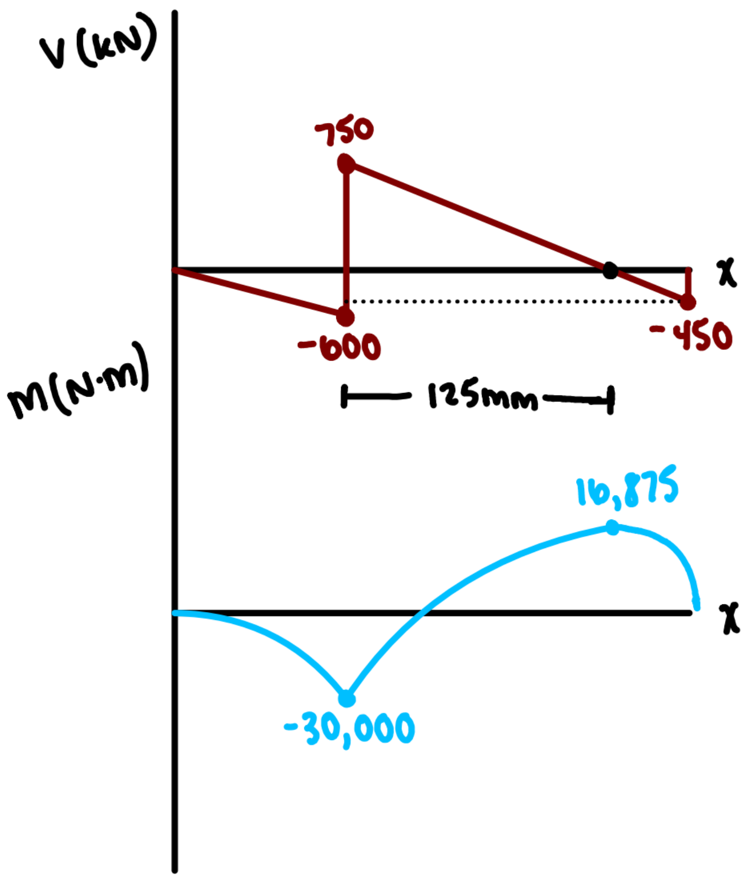
$A_y + B_y = 1800$

$200A_y = 270000$

$A_y = 1350$

$B_y = 450$

The shear and moment diagram is,



The maximum shear and tensile stress occur at $x = 100\ mm$.

[3]:
```python
# Calculating stress due to bending
M, c = 30_000, sp.S(0.025)
(M*c/(sp.pi/4*c**4)).n()  # in Pa
```

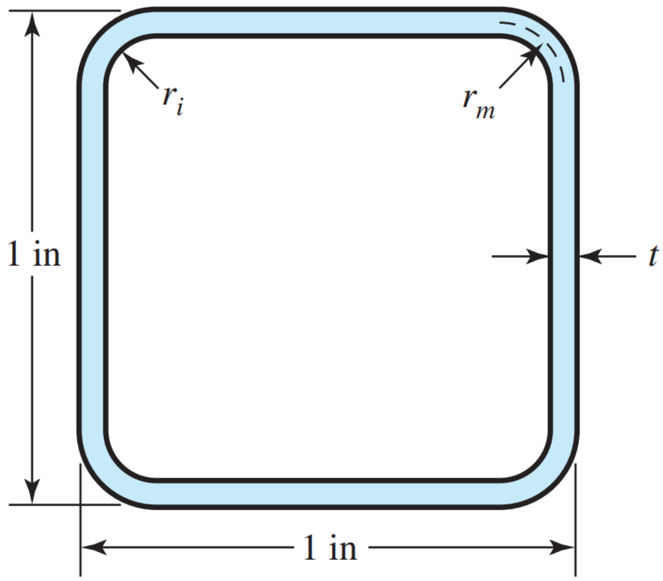
[3]: 2444619925.89151

[4]:
```
# Calculating the maximum shear stress
V = 750_000
(sp.Rational(4, 3)*V/(sp.pi*c**2)).n()  # in Pa
```

[4]: 509295817.894065

2 Problem 3-62 Part A

2.1 Given



The tube is 36 *in* long and $r_i = r_m = 0$. The thickness t is $\frac{1}{16}$".

2.2 Find

The maximum torque that can be applied and the corresponding angle of twist of the tube.

2.3 Solution

For thin-walled tubes,

$$\tau = \frac{T}{2A_m t}$$

$$\theta_1 = \frac{TL_m}{4GA_m^2 t}$$

See p. 129 for additional details of the above formulas.

[5]:
```
# Calculating the maximum torque
tau_max = 12_000  # lbf in
t = sp.Rational(1, 16)  # thickness in inches
Am = (1 - t)**2
T = tau_max*2*Am*t
T.n()  # lbf in
```

[5]:

1318.359375

From table A-5, the modulus of rigidity is 11.5 $Mpsi$.

[6]:

```
G = 11.5e6
Lm = (1 - t)*4  # total length
L = 36  # inches
phi_1 = T*Lm/(4*G*Am**2*t)*L
(phi_1*180/sp.pi).n()  # in degrees
```

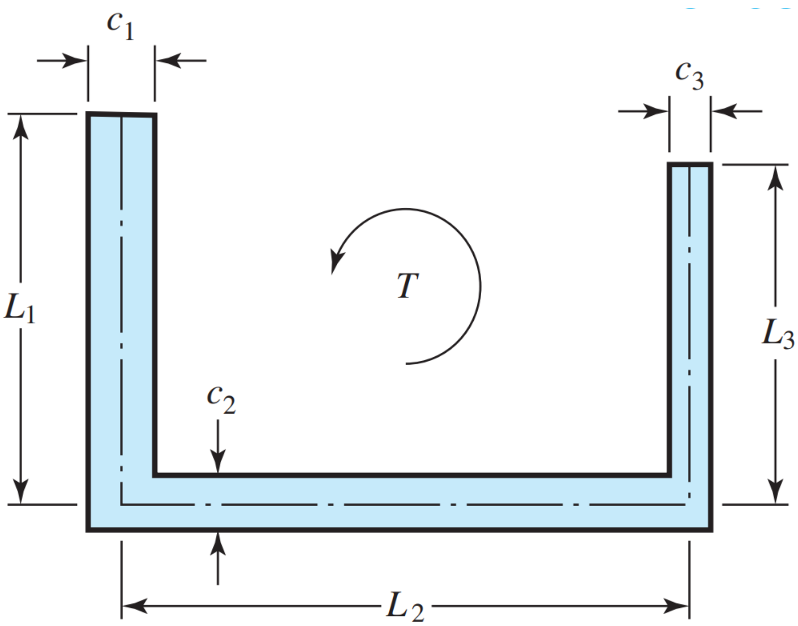
[6]:

4.59163394776145

The expression gets multiplied by L because θ_1 is the angle of twist per unit length.

3 Problem 3-64

3.1 Given



$c_1 = 2\ mm$, $L_1 = 20\ mm$, $c_2 = 3\ mm$, $L_2 = 30\ mm$, $c_3 = 0\ mm$, and $L_3 = 0\ mm$. The material is steel and the maximum shear is $\tau_{allow} = 12\ ksi$. The angle of twist is the same for each section.

3.2 Find

a. Determine the torque transmitted by each leg and the torque transmitted by the entire section.
b. Determine the angle of twist per unit length.

3.3 Solution

The relationship for open looped geometry is,

$$T_i = \frac{\theta_i G L_i c_i^3}{3}$$
$$\tau_{max} = G\theta_i c_{max}$$

From Table A-5, $G_{steel} = 79.3\ GPa$. I will find Part B first because it is required to answer Part A.

3.3.1 Part B

[7]:
```
tau_max = sp.S(82.7371e6)  # shear stress in Pa
G = sp.S(79.3e9)  # modulus of rigidity in Pa
c = [sp.S(c_) for c_ in (0.002, 0.003, 0)]  # in m
L = [sp.S(L_) for L_ in (0.02, 0.03, 0)]  # in m
c_max = max(c)

phi_i = tau_max/(G*c_max)
phi_i  # in rad per m
```

[7]: 0.347781000420345

3.3.2 Part A

[8]:
```
T = []
for i in range(len(c)):
    T_i = phi_i*G*L[i]*c[i]**3/3
    display(sp.Eq(sp.Symbol(f'T_{i + 1}'), T_i))
    T.append(T_i)
T = sum(T)
display(sp.Eq(sp.Symbol('T'), T))  # torques in N m
```

$T_1 = 1.47088177777778$

$T_2 = 7.446339$

$T_3 = 0$

$T = 8.91722077777778$