

Machine Design Homework 2

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

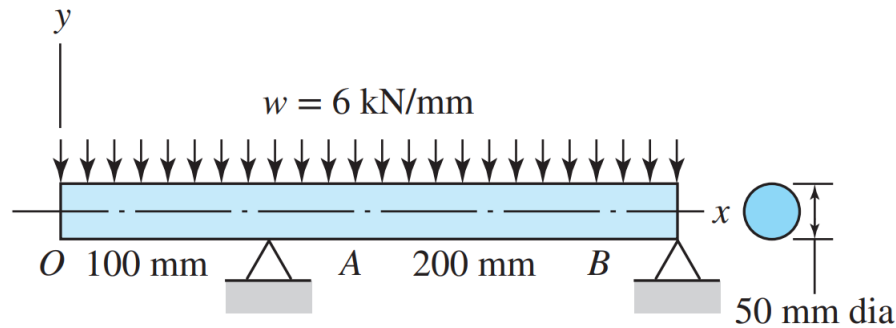
plt.style.use('maroon_ipynb.mplstyle')
```

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1 Problem 3-39

1.1 Given

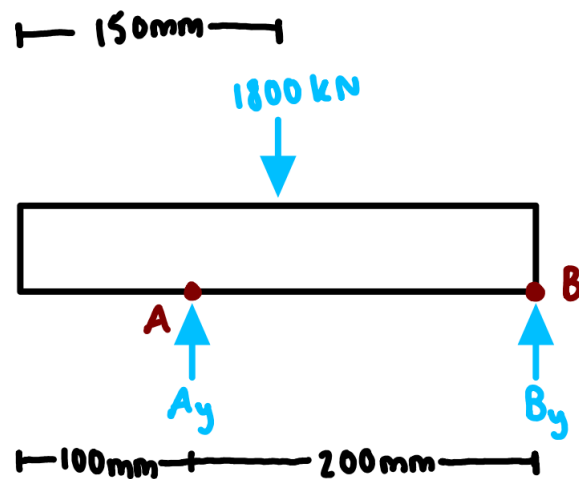


1.2 Find

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]]
```

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

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

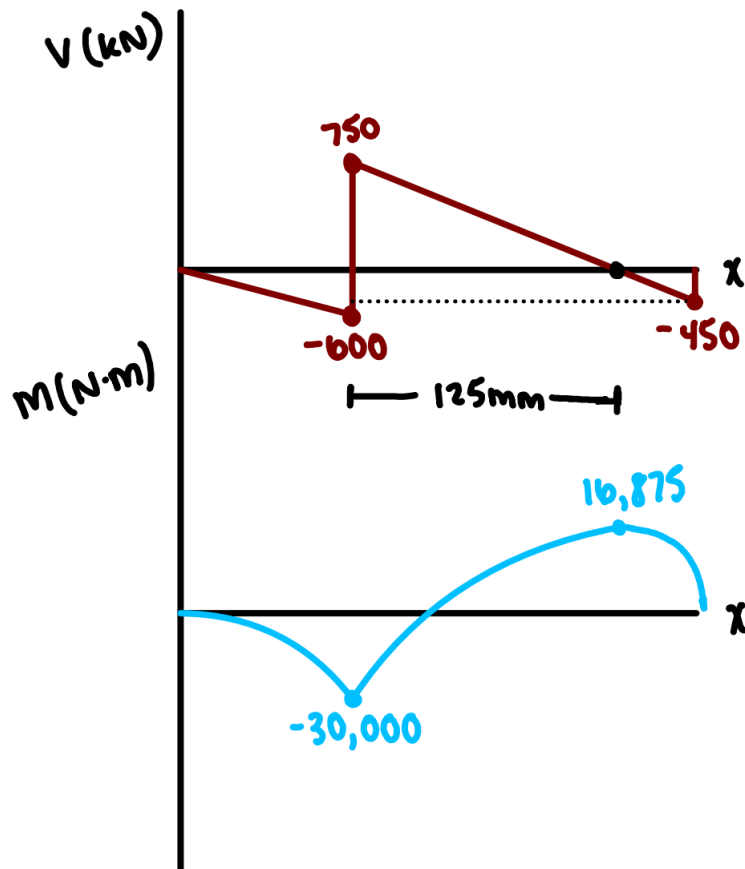
$$A_y + B_y = 1800$$

$$200A_y = 270000$$

$$A_y = 1350$$

$$B_y = 450$$

The shear and moment diagram is,



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

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

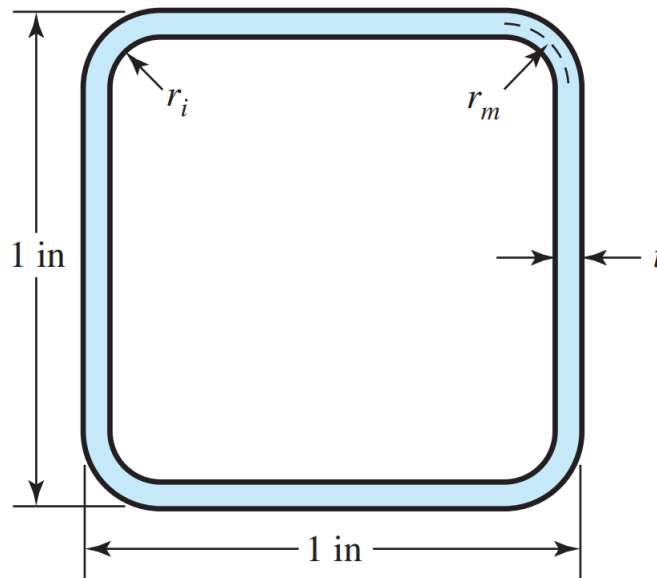
```
[3]: 2444619925.89151
```

```
[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 $\frac{1}{16}$ in.

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*.

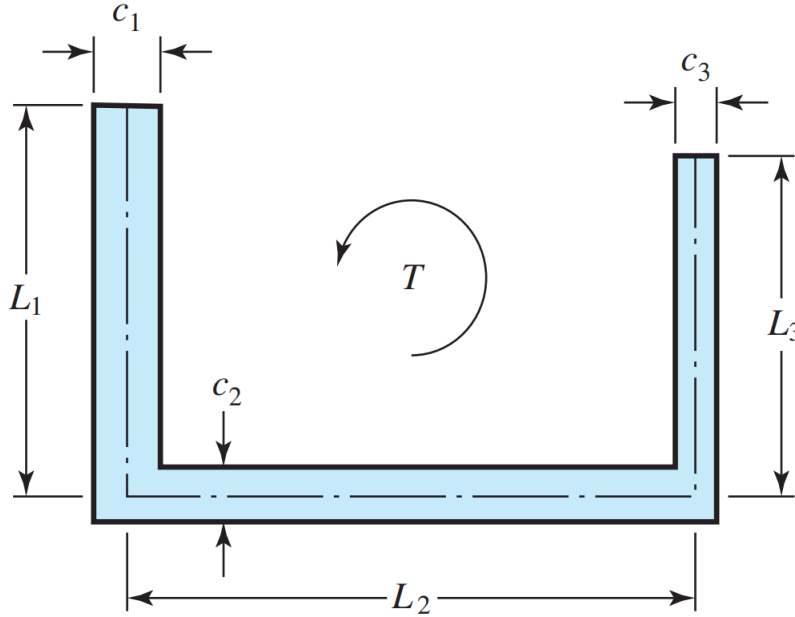
```
[6]: G = 11.5e6
      Lm = (1 - t)*4 # total length
      L = 36 # inches
      phi_1 = T*Lm/(4*G*Am**2*t)*L
      (phi_1*180/sp.pi).n() # in degrees
```

[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



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

3.2 Find

- Determine the torque transmitted by each leg and the torque transmitted by the entire section.
- 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, $G_{steel} = 79.3 \text{ GPa}$. 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
```

$$T_1 = 1.47088177777778$$

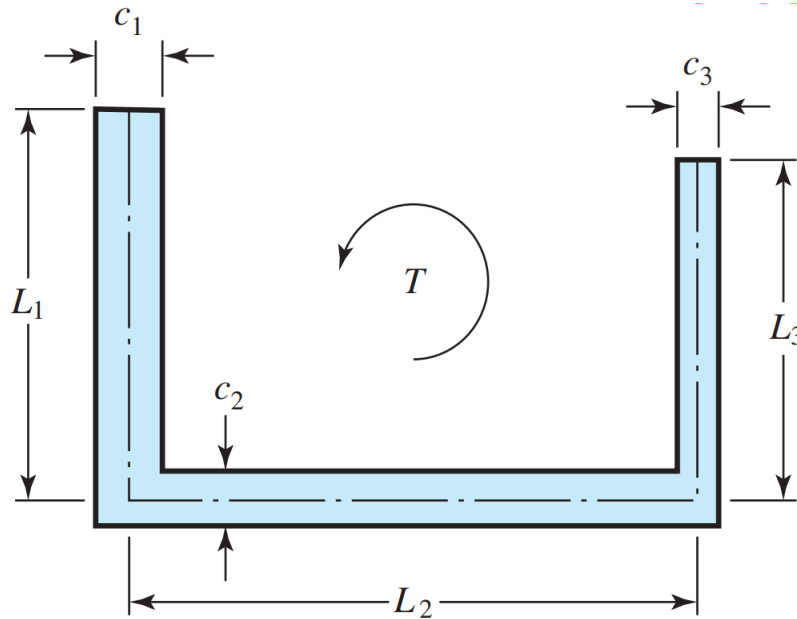
$$T_2 = 7.446339$$

$$T_3 = 0$$

$$T = 8.91722077777778$$

4 Problem 3-64

4.1 Given



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

4.2 Find

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

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

4.3.1 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
```

4.3.2 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
```

$$T_1 = 1.47088177777778$$

$$T_2 = 7.446339$$

$$T_3 = 0$$

$$T = 8.91722077777778$$