HW7

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Group number
3

Group members
Alexander Stoustrup
Mathias Tyranski
Benjamin Simonsen

```python
[1]: import numpy as np
     from scipy.optimize import minimize
     import scipy.signal as si
     import sympy as sp
     import control as ct
     from typing import List
     from sympy.plotting import plot
     import matplotlib.pyplot as plt
     from IPython.display import display, Latex, Math, Image
     %matplotlib inline

     def eq_disp(varstring, expr, unit=""):
         display(Latex(f"${varstring}={sp.latex(expr)} \: {unit}$"))


     def reduce_feedback(G_fwd, G_bwd):
         """Assumes feedback is deducted from signal, if not
         change sign of feedback"""
         return sp.simplify(G_fwd/(1+G_fwd*G_bwd))
```

0.1 Problem 1

```python
[2]: P, L, h, E, I, X, Vi, F=sp.symbols('P, L, h, E, I, X, V_i, F')
     eps1 = P*(L+X)*h/(2*E*I)
     eps2 = P*L*h/(2*E*I)
     eps3 = P*(L+X)*-h/(2*E*I)
     eps4 = P*L*-h/(2*E*I)


     Vo = (1/4*F*(eps3-eps4+eps2-eps1)*Vi).simplify()
     eq_disp("V_o", Vo)
```

$V_o = -\frac{0.25 F P V_i X h}{EI}$

L doesnt have an influence on the measured strain. This setup measures strain at the clamp as if P was applied at distance X instead of L. the advantage of the system is that it doesnt matter where the load is applied - (the value of L doesnt matter)

0.2   Problem 2

```
[3]: d = 0.25
     A = d**2/4*np.pi
     R = 120
     dR = 0.01
     F = 500
     E = 30*10**6
```

We can calulate the axial stress. The stress is proportional to the strain through the youngs modulus so we can find strain

```
[4]: sigma = F/A
     axial_strain = sigma/E
```

Now by the definition of the Gauge factor we calculate it

```
[16]: GF = dR/R/axial_strain
      eq_disp("GF", GF)
```

$GF = 0.0445110441696305$

0.3   Problem 3

```
[6]: E = 200
     d = 10
     F = 50
     A = d**2/4*np.pi
     GF = 2.115
     R = 120
```

Stress in the bar is:

```
[7]: sigma = F/A
     eq_disp('\sigma',round(sigma,5), "GPa")
```

$\sigma = 0.63662\,GPa$

Strain is:

```
[8]: strain = sigma/E
```

From the definition of gauge factor we find ΔR

```
[9]: dR = GF*strain*R
     eq_disp("\Delta R", round(dR,5))
```

$$\Delta R = 0.80787$$

For a One-Gauge bridge measurement the ouput voltage is

```
[10]: Vo = 1/4*dR/R*Vi
      eq_disp("V_{out}",sp.N(Vo,5))
```

$$V_{out} = 0.0016831 V_i$$

0.4   Problem 4

```
[11]: GF = 3
      R  = 1000
      L  = 100   #mm
      t  = 20   #mm
      w  = 40   #mm
      A  = t*w
      E  = 73.1
```

0.4.1   1)

```
[12]: F = 1*9.82/1000 #kN
      I = w*t**3/12
```

Assuming the strain gauge is mounted at the fixed end and assuming the load is applied as a transverse load the strain will be

```
[13]: strain = F*(L)*t/(2*E*I)
```

The additional resistance can now be calculated from the gauge factor

```
[14]: dR = GF*strain*R
      eq_disp("R", round(dR+R,5))
```

$$R = 1000.01511$$

0.4.2   2)

The voltage between the terminals is calculated from the strain

```
[15]: Vin = 5
      Vout = 1/4*GF*strain*Vin
      eq_disp("V_{out}", round(Vout,10), "V")
```

$$V_{out} = 1.88911 \cdot 10^{-5} \ V$$