University of São Paulo
São Carlos School of Engineering

PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA MECÂNICA

Admission Exam PPG-EM – 2023/2º sem

Candidate Name:	
ID:	
Date:	
Signature:	

Instructions

1) The exam consists of 10 questions, and the candidate must choose 5 questions to solve. In case the candidate solves a greater number of questions, only the first 5 will be considered;
2) All questions have the same value (2.0 points for each question);
3) It is not allowed to consult any type of material;
4) The use of simple (non-programmable) electronic calculators is permitted;
5) All answers must be justified;
6) The duration of the exam is 3 hours.

For the exclusive use of examiners

QUESTIONS SCORES									
Q1		Q3		Q5		Q7		Q9	
Q2		Q4		Q6		Q8		Q10	

TOTAL SCORE	

Graduate Program in Mechanical Engineering
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QUESTION 1: (Linear Algebra)

Given that the determinant of the square matrix below is:

$$\begin{vmatrix} 2 & a & b \\ c & d & 5 \\ e & -4 & f \end{vmatrix} = 50$$

Calculate:

a) $\begin{vmatrix} c & d & 5 \\ 2 & a & b \\ e & -4 & f \end{vmatrix}$

b) $\begin{vmatrix} 2 & a & b \\ -6 & -3a & -3b \\ e & -4 & f \end{vmatrix}$

Justify your answer.

QUESTION 2: (Differential and Integral Calculus)

a) The vibration amplitude of a spring-mass-damper system subjected to a harmonic excitation $F\sin(\Omega t)$ is given by:

$$A = \frac{F/k}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$

Find the value of r that maximizes the vibration amplitude A.

b) Solve the integral:

$$\int_0^{\pi} e^x cos(x) dx$$

Justify your answer.

QUESTION 3: (Computation)

Consider the Python code below:

a) What is printed on the screen when the function **main** is executed?

b) What would be printed to the screen if it were incorporated the function **query(raiz, 14)** and **query(raiz, 28)** on lines 105 and 106, respectively?

```
1  class No:
2      def __init__(self, data: int):
3          self.data = data
4          self.right_filho = None
5          self.left_filho = None
6  
7  def insert(raiz: No, x: int) -> No:
8      if raiz is None:
9          return No(x)
10     elif x > raiz.data:
11         raiz.right_filho = insert(raiz.right_filho, x)
12     else:
13         raiz.left_filho = insert(raiz.left_filho, x)
14     return raiz
15 
16 def search(raiz: No, x: int) -> No:
17     if (raiz is None) or (raiz.data == x):
18         return raiz
19     elif x > raiz.data:
20         return search(raiz.right_filho, x)
21     else:
22         return search(raiz.left_filho, x)
23 
24 def find_minimum(raiz: No) -> No:
25     if raiz is None:
26         return None
27     elif raiz.left_filho is not None:
28         return find_minimum(raiz.left_filho)
29     return raiz
30 
31 def apague(raiz: No, x: int) -> No:
32     if raiz is None:
33         return None
34 
35     if x > raiz.data:
36         raiz.right_filho = apague(raiz.right_filho, x)
37     elif x < raiz.data:
38         raiz.left_filho = apague(raiz.left_filho, x)
39     else:
40         if (raiz.left_filho is None) and (raiz.right_filho is None):
41             raiz = None
42         elif (raiz.left_filho is None) or (raiz.right_filho is None):
43             temp = None
44             if raiz.left_filho is None:
45                 temp = raiz.right_filho
46             else:
47                 temp = raiz.left_filho
48             raiz = None
49             return temp
50         else:
51             temp = find_minimum(raiz.right_filho)
52             raiz.data = temp.data
53             raiz.right_filho = apague(raiz.right_filho, temp.data)
54 
55     return raiz
56 
57 def manipule(raiz: No) -> None:
58     if raiz is not None:
```

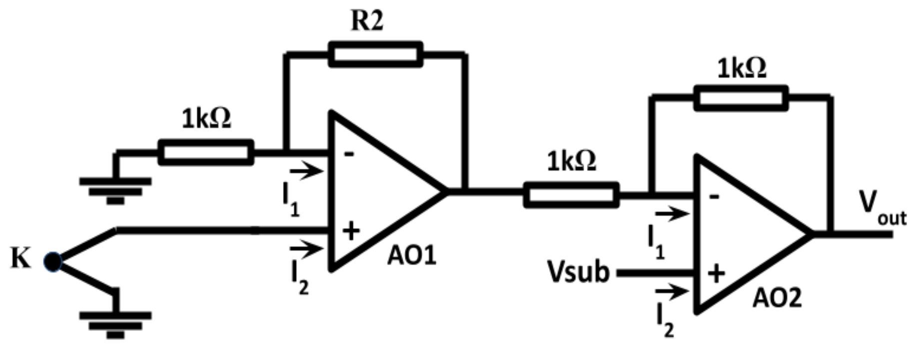
QUESTION 3: (Computation - continuation)

```
        manipule(raiz.left_filho)
        print(f" {raiz.data} ", end='')
        manipule(raiz.right_filho)

def query(raiz: No, x: int) -> None:
    if raiz is not None:
        if raiz.data == x:
            print(f"query {x}: ", end='')
            if raiz.left_filho is not None:
                print(f" {raiz.left_filho.data} ", end='')
            else:
                print(' 0 ', end='')
            print(f" {raiz.data} ", end='')
            if raiz.right_filho is not None:
                print(f" {raiz.right_filho.data} ", end='')
            else:
                print(' 0 ', end='')
            print("\n", end='')
        else:
            query(raiz.left_filho, x)
            query(raiz.right_filho, x)

def main():
    raiz = No(21)
    raiz = insert(raiz, 6)
    raiz = insert(raiz, 1)
    raiz = insert(raiz, 13)
    raiz = insert(raiz, 11)
    raiz = insert(raiz, 7)
    raiz = insert(raiz, 14)
    raiz = insert(raiz, 28)
    raiz = insert(raiz, 27)
    raiz = insert(raiz, 42)
    raiz = insert(raiz, 47)
    raiz = insert(raiz, 50)
    raiz = insert(raiz, 37)

    manipule(raiz)
    print("\n", end='')

    raiz = apague(raiz, 13)
    raiz = apague(raiz, 42)

    manipule(raiz)
    print("\n", end='')





if __name__ == "__main__":
    main()
```

Justify your answer.

QUESTION 4: (Electronics)

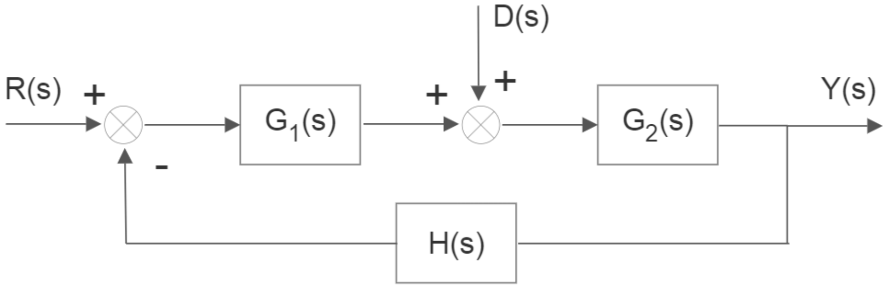
According to the presented circuit, one must amplify the signal of a K-type thermocouple sensor and adjust the Vout voltage, for the input of an A/D converter, between -5 V and 0 V. The temperature range of interest is between 10 degrees Celsius and 50 degrees Celsius, where the thermocouple voltage variation range is from 0.41 mV to 2.05 mV. Determine the value of R2 in the first amplification stage and the value of the voltage level Vsub to be subtracted in the second stage.



Justify your answer.

QUESTION 5: (Control Systems)

A closed-loop system has the following block diagram:



where $Y(s)$ is the system output, $R(s)$ is the reference, D(s) is the disturbance, and $G_1(s)$, $G_2(s)$ and $H(s)$ are transfer functions.

Describe the output $Y(s)$ in terms of the inputs $R(s)$ and $D(s)$.

Justify your answer.

QUESTION 6: (Materials)

a) Draw, schematically, the relative stress-strain diagram for the following materials:

1. cast iron,
2. low-carbon steel, and
3. aluminum.

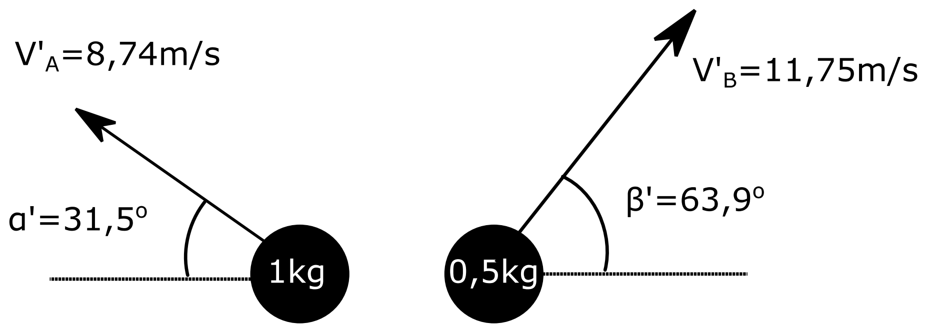
On each graph, indicate the ultimate stress, ultimate strength, yield strength, and percent elongation.

b) Among the materials 1, 2 and 3 in item a), which is easier to cold-form? Which one has the worst formability? Explain.

Justify your answer.

QUESTION 7: (General Mechanics)

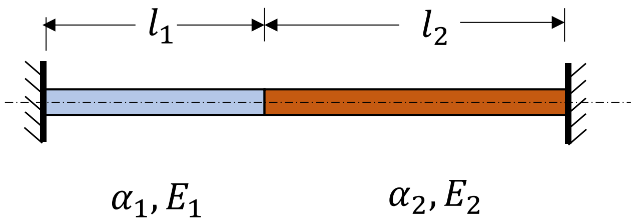
Knowing the final conditions after the impact between two spheres of mass m_A = 1 kg and m_B = 0,5 kg given by the following figure, find the initial condition just before the impact (speeds, V_A and V_B, and angles, α and β), considering an coefficient of restitution e = 0,9.



Justify your answer.

QUESTION 8: (Solid Mechanics)

A constant-section dowel is made from two segments of different metals and is supported between two rigid walls as shown by the figure:



Calculate the force one segment exerts on the other when the temperature is increased by ΔT °C.

Where: α is the linear thermal expansion; E is the modulus of elasticity and l is the length.

Justify your answer.

QUESTION 9: (Thermodynamics)

Air enters a compressor of a gas turbine installation at ambient conditions of 100 kPa and 25ºC with a low velocity and leaves the compressor at a pressure of 1MPa and a temperature of 347ºC, with a velocity of 90 m/s. The compressor is cooled at a rate of 1500 kJ/min, providing a mass flow rate of compressed air equal to 0.75 kg/s and operating at steady state. Determine:

(a) The power supplied to the compressor in kW.

(b) Assuming that water is used to cool the compressor, determine the required mass flow rate of water to supply the given cooling rate, so that the water temperature variation (between inlet and outlet) is 10°C. In this case, the water flows through the external side of the compressor shell. Assume the c_p of water constant and equal to 4179 J/(kg*K).

Assume that air behaves like an ideal gas with the following average properties:

(R = 287.0 J/(kg*K) and c_p = 1.020 kJ/(kg*K)).

Formulae:
Mass conservation:

$$\frac{\mathrm{d}m_{\mathrm{vc}}}{\mathrm{dt}} = \sum_e \dot{m}_e - \sum_s \dot{m}_s$$

Energy conservation:

$$\dot{Q}_{\mathrm{vc}} = \frac{\mathrm{dE_{vc}}}{\mathrm{dt}} + \sum_s \dot{m}_s \left(h_s + \frac{V_s^2}{2} + \mathrm{gz}_s\right) - \sum_e \dot{m}_e \left(h_e + \frac{V_e^2}{2} + \mathrm{gz}_e\right) + \dot{W}_{\mathrm{vc}}$$

Equation of state for an ideal gas: $Pv = \mathrm{RT}$

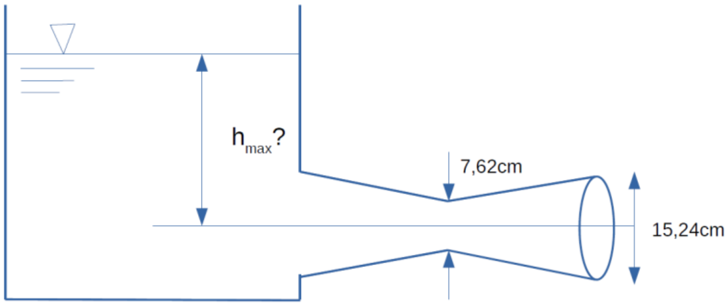
Where: $\dot{W}$ – Power [W]; E – Total energy [J]; $\dot{Q}$ – Heat Transfer Rate [W]; - Mass flow rate [kg/s]; m – mass [kg]; T – temperature [K]; t – time [s]; g – gravitational acceleration [m/s^2]; z – height [m]; V – fluid velocity [m/s]; h - specific enthalpy [J/kg]; v – specific volume [m^3/kg]; P – Thermodynamic pressure [Pa]; R – Gas constant (air) [J/(kg*K)]; c_p – Specific heat at constant pressure [J/(kg*K)].

Subscripts: vc – control volume, s – output, e – input.

Justify your answer.

QUESTION 10: (Fluid Mechanics)

Consider a large tank. How high above the centerline of a convergent-divergent nozzle, through which a jet of water exits to the atmosphere, can the water level be raised so that the pressure at the throat of the nozzle equals the vapor pressure of the water (3,447.38 Pa-abs)? Assume atmospheric pressure of 101,353.00 Pa and neglect shear. What would happen if the surface of the water were raised above this level?



Data: ρ = 1000 kg/m³, g = 9,81 m/s².

Formulae:

Mass conservation: $V_1 A_1 = V_2 A_2$

Bernoulli's Equation:

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + h_2$$

where: V – velocity [m/s]; A – area [m²]; p – pressure [Pa]; ρ – density [kg/m³]; g – gravity acceleration [m/s²]; h – height [m].

Justify your answer.