Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ USC ID#: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

I hereby affirm that all the answers below are my own. I have neither searched online nor taken assistance from any external entity.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Student Signature Above

EE105 – Fall 2024

Final

Time Limit:

Section 1: /25

Section 2: /25

Section 3: /25

Total: /75

Total number of pages is (excluding this page). Put your name on every page where noted

**Section A (25 points)**

**Question 1 (5 points)**

You are provided with a temperature sensor characterized by a resistance vs. temperature curve. The circuit includes three fixed resistors, R1=R2=R3=100 Ω, which remain constant regardless of temperature, and a temperature-sensitive resistor RT​ (the temperature sensor). Determine the output voltage Vout at temperatures of 25∘C and 30∘C.

A diagram of a circuit

Description automatically generatedA graph of temperature and temperature

Description automatically generated

**Question 2 (4 points)**

**A)** The transistors are arranged in the circuit configuration shown in the diagram below (PMOS on top and NMOS in bottom). Complete the table by determining the output voltage (Vout​) for each corresponding input voltage (Vin​) listed in the table.

**A diagram of a circuit

Description automatically generated**

|  |  |
| --- | --- |
| **Vin** | **Vout** |
| **0** |  |
| **VDD** |  |

**B)** The circuit consists of transistors cascaded from T1 to T 2×106​, as illustrated in the diagram below. Complete the table by calculating the output voltage (Vout) for each corresponding input voltage (Vin​) provided in the table.

**A diagram of a circuit

Description automatically generated**

|  |  |
| --- | --- |
| **Vin** | **Vout** |
| **0** |  |
| **VDD** |  |

**Question 3 (5 points)**

A photodiode generates a current of 1 nA (10-9 A) when illuminated by light from an LED. Design a circuit to produce an output voltage of −1 V when the photodiode is exposed to the LED's light.

**Question 5 (2 points)**

The diagram shows the frequency response of a signal. To isolate a frequency of 20 Hz, what type of filter would you use?

A graph of frequency and frequency

Description automatically generated

**Question 6 (5 points)**

A circuit contains two diodes, each with a threshold voltage of Vt = 0.7 V. The diodes are forward-biased and connected in series. The anode of the first diode is connected to the positive terminal of a 3.3 V battery. The cathode of the first diode is connected to the anode of the second diode. The cathode of the second diode is connected to the negative terminal of the battery through a wire.

The wire connecting the cathode of the second diode to the battery has a length of 1 m, a diameter of 200 μm, and a resistivity of ρ = 1.7×10−8 Ω⋅m. Assume the diodes are ideal apart from the threshold voltage.

1. Draw the circuit diagram.
2. Calculate the current flowing through the wire.

**Section B (25 points)**

**Question 7**  (4 points)

Given matrices A and B: A = [[2, -1, 3], [0, 4, -2], [1, -3, 5]] B = [[1, 0, 2], [3, -1, 4], [-2, 1, 0]]   
a) Calculate AB and BA. Are they equal? Explain why or why not. b) Find det(A) c) Calculate the eigenvalues of A d) Determine if A is invertible, and if so, find A⁻¹

**Question 8**  (5 points)

A dataset contains these points: (1,3), (2,5), (3,4), (4,7), (5,8)   
a) Calculate the least squares regression line   
b) Calculate the error of your fit assuming a least square error cost function.   
c) Predict the y-value for x = 6 using your model   
d) Explain whether this prediction is interpolation or extrapolation and discuss its reliability

**Question 9** (8 points)

Consider a neural network for binary classification with:

* + Input layer: 3 neurons
  + Hidden layer: 4 neurons with ReLU activation
  + Output layer: 1 neuron with sigmoid activation

Given the input [1, 0, 1]: a) Calculate the output if the weights and biases are given as follows:

* + Hidden layer weights: [[0.1, 0.2, -0.1], [-0.2, 0.3, 0.2], [0.4, -0.3, 0.1], [0.1, 0.1, -0.2]]
  + Hidden layer bias: [0.1, -0.1, 0.2, 0.1]
  + Output layer weights: [0.3, -0.2, 0.4, 0.1]
  + Output layer bias: [-0.1]

b) Draw the neural network with each weight and bias labeled

**Question 10**  (8 points)

For a neural network training on MNIST: a) Calculate the total number of parameters for a network with:

* + Input: 784 neurons (28×28 pixels)
  + Hidden layer 1: 128 neurons
  + Hidden layer 2: 64 neurons
  + Output: 10 neurons

b) Estimate the memory required to store this network assuming all values are 16 bits.

c) Calculate the number of multiply-add operations for one forward pass

**Section C (25 points)**

**Question 11 ( 10 points)**

A fiber optic communication system uses a glass fiber with refractive index n₁ = 1.48 and cladding with refractive index n₂ = 1.46. a) Calculate the critical angle for total internal reflection at the core-cladding interface. b) If light enters the fiber at an angle of 15° relative to the fiber axis in air (n = 1.0), determine if this ray will propagate through the fiber.

**Question 12 (15 points)**

An optical detector system consists of:

* + A photodiode operating at reverse bias of 5V
  + A resistor for converting current to voltage with resistance of 50kΩ
  + Incident light producing 2μA of photocurrent

Calculate: a) The output voltage of the resistor

b) The RMS noise voltage if the system bandwidth is 1MHz and the photodiode dark current is 1nA. Consider the noise current sources to be thermal noise, shot noise from the photocurrent, and shot noise from the photodiode dark current.

c) The signal-to-noise ratio (not in DB, just the ratio)