Problem 1  (3 points) In the process of photolithography, which of the following is removed during the etching step?

- a. Photoresist that was broken down by light
- b. Photoresist that was not broken down by light
- c. Metal that is protected by photoresist
- d. Metal that is not protected by photoresist
- e. Metal that was broken down by light
- f. Metal that was not broken down by light

Answer: d

RTD-related

Problem 2  (3 points) In the photolithography process, which type of electromagnetic radiation breaks down one of the substances for easy removal?

- a. Radio waves
- b. Microwaves
- c. Infrared light
- d. Visible light
- e. Ultraviolet light
- f. X-rays
- g. Gamma rays

Answer: e
Problem 3

(3 points) Without doing any calculations, which piece of wire listed in the table would you expect to have the highest resistivity?

<table>
<thead>
<tr>
<th>Piece</th>
<th>Material</th>
<th>Length</th>
<th>Diameter</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Copper</td>
<td>30m</td>
<td>1mm</td>
<td>0.64Ω</td>
</tr>
<tr>
<td>B</td>
<td>Copper</td>
<td>30m</td>
<td>0.3mm</td>
<td>7.09Ω</td>
</tr>
<tr>
<td>C</td>
<td>Copper</td>
<td>30m</td>
<td>0.1mm</td>
<td>638Ω</td>
</tr>
<tr>
<td>D</td>
<td>Copper</td>
<td>100m</td>
<td>0.1mm</td>
<td>213Ω</td>
</tr>
<tr>
<td>E</td>
<td>Copper</td>
<td>10m</td>
<td>1mm</td>
<td>0.21Ω</td>
</tr>
</tbody>
</table>

a. A  
b. B  
c. C  
d. D  
e. E  
f. All about the same  
g. Not enough information

Answer: f

\[
R = \frac{\rho L}{A} = \frac{\pi \rho L}{4}
\]

Problem 4

(3 points) Suppose you want to cool a warm piece of metal by dipping it in a bowl containing 1 kg of liquid. You want to select the liquid that will experience the smallest increase in temperature for any given piece of metal. Based on the data below, which liquid do you put in the bowl?

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Specific Heat J/(kg·°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>4600</td>
</tr>
<tr>
<td>Glycerine</td>
<td>2430</td>
</tr>
<tr>
<td>Olive oil</td>
<td>1970</td>
</tr>
<tr>
<td>Propylene Glycol</td>
<td>2500</td>
</tr>
<tr>
<td>Water</td>
<td>4190</td>
</tr>
</tbody>
</table>

a. Ammonia    
b. Glycerine   
c. Olive Oil   
d. Propylene Glycol   
e. Water

Answer: a
Problem 5

(3 points) If using one of the RTD's that we made in the lab, why do we need to use the INTERNAL analog reference for measuring voltage?

a. Allows the system to detect a wider range of temperatures
b. Allows the system to detect a smaller change in temperature
c. Causes the analog output value to increase when temperature increases
d. Removes restrictions on the choice of resistor value for \( R_{\text{LOWER}} \)
e. Makes life more difficult for students

Answer: b

Problem 6

(3 points) What do we call a situation where the condition of a system is not changing with time? An example is the mass of a lake remaining constant because the water entering equals the water leaving.

a. "Constant conditions"
b. "Change cancellation"
c. "Transient"
d. "Perpetual stability"
e. "Steady State"
f. "Perfection"

Answer: e
Problem 7

(3 points) Which of the following is NOT an advantage of using the thermistor (as opposed to using the RTD) in our fishtank project?

a. Analog output increases with temperature increase
b. Measures a wider range of temperatures
c. More sensitive to temperature changes
d. Faster response to temperature changes
e. Simpler programming
f. Special calculations for $R_{lower}$ value not required

Answer: b

Problem 8

(3 points) According to the first law of thermodynamics, what is equal to the energy coming into a system minus the energy going out of that system?

$\Delta E_{sys} = E_{in} - E_{out}$

a. Change in energy in the system
b. Total energy in the system
c. Change in energy in the universe
d. Total energy in the universe
e. Total mass and energy in the universe
f. Zero
g. Not enough information

Answer: a
Problem 9
(3 points) The first law of thermodynamics is often written as follows:

\[ Q - W = \Delta E \]

What is Q in this equation?

- a. Work done by the system
- b. Work done on the system
- c. Heat transfer to the system
- d. Heat transfer from the system
- e. Quietness factor
- f. Quiznos constant
- g. Queen of England
- h. Quite beyond what I can recall

Answer: c

Problem 10
(3 points) Generally it is good to have a small deadband (UCL-LCL). This way a system will strive to regulate the conditions more carefully and to keep conditions very close to the setpoint. However, what problem might occur if the deadband is too small?

- a. No problem; the smaller the better
- b. System might give up if it feels the demands are too high
- c. System might not respond to large disturbances at all because they are too far outside control limits
- d. System might not be precise enough to bring conditions within control limits, resulting in repeated overshoot and oscillation

Answer: d
Problem 11
(5 points) A 300 Watt electric heater is immersed in a container with unknown volume of water. If it takes 10 minutes to heat the water up by 5 degrees Celsius, then the volume of water is closest to . . . .

a. 8.6 L
c. 10.5 L
d. 13.2 L
e. 18.3 L
f. 26.1 L
g. 48.3 L
h. 61.1 L

\[ P = 300 \cdot W \quad t = 10 \cdot min \quad \rho = 1 \cdot \frac{kg}{L} \quad C_p = 4180 \cdot \frac{J}{kg \cdot K} \quad \Delta T = 5 \cdot K \]

\[ Vol = \frac{P \cdot t}{\rho \cdot C_p \cdot \Delta T} = 8.612 \ L \]

Problem 12
(5 points) You pour 1 kg of deionized water into a bottle that contains 1 mol of NaCl. The %wt of NaCl in the solution is closest to . . .

a. 1.1%
b. 2.2%
c. 3.3%
d. 4.4%
e. 5.5%
f. 6.6%
g. 7.7%
h. 8.8%
i. 9.9%

\[ MW = \frac{23 + 35.5}{1000} \cdot \frac{kg}{mol} \quad mass_{NaCl} = MW \cdot 1 \cdot mol = 0.059 \ kg \quad mass_{H2O} = 1 \cdot kg \]

\[ percent\_weight = \frac{mass_{NaCl}}{mass_{NaCl} + mass_{H2O}} \cdot 100 = 5.527 \]
Problem 13

(5 points) If your conductivity sensor produces 1 mol of H₂ gas over a 24 hour period, then the average electrical current flowing to the sensor is closest to . . .

  a. 3.25 mA
  b. 8.31 mA
  c. 112 mA
  d. 852 mA
  e. 1.01 A
  f. 2.23 A
  g. 3.90 A
  h. 8.11 A

\[
2 \text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^- \text{ electrons per mol H}_2\text{O}
\]

\[
\text{current} = \frac{1 \text{ mol H}_2}{2 \text{ mol H}_2\text{O}} \times \frac{1 \text{ mol H}_2}{2 \text{ mol H}_2\text{O}} \times \frac{2\text{e}^-}{1 \text{ mol H}_2\text{O}} \times \frac{6.24 \times 10^{23}}{6.022 \times 10^{23}} \text{coulombs per day} = 2.23 \text{ A}
\]

Problem 14

(5 points) Typical whole cow milk has the following composition:

87.8% water; 4.8% carbohydrates; 3.9% fat; 3.5% protein & other stuff

A shady vendor is adding pure sugar (assume pure sugar is composed of 100% carbohydrates) and water to produce phony milk with 2% fat. If the percent weight of carbohydrates in the phony milk remains 4.8% while the percent weights of the other components are allowed to change, then the amount of water that must be added to 1 kg of whole milk to produce this phony 2% fat milk is closest to . . .

a. 11 g
b. 25 g
c. 31 g
d. 120 g
e. 387 g
f. 611 g
\(1004 \text{ } g\)
h. 2.1 kg

\[
\begin{align*}
\text{water in whole milk} & = 0.385 \times 1004 \\
\text{sugar in whole milk} & = 0.009 \times 1004 \\
\text{carbohydrates in whole milk} & = 0.385 \times 1004 + 0.009 \times 1004 \\
\text{fat in whole milk} & = 0.039 \times 1004 \\
\text{protein & other stuff in whole milk} & = 0.350 \times 1004 \\
\end{align*}
\]

\[
\begin{align*}
x + y & = 2 \\
0.048x + 0.068y & = 2 \\
\end{align*}
\]

\[
\begin{align*}
x & = 2 - 1-y \\
y & = 0.048(1-y) + 0.385 \\
x & = 0.048(1-y) + 0.385 \\
\end{align*}
\]

\[
\begin{align*}
x & = 0.956 y \\
y & = 0.044 y \\
\end{align*}
\]
Problem 15
(5 points) A 30 Ω resistor connected to a 12VDC power supply will be used to heat the water in a small fishtank with a volume of 3 liters. If the initial temperature of the water if 15 °C, then the temperature of the water after 17.5 minutes of heating (assuming no heat loss) will be closest to . . .

d. 15.4 °C

\[R = 30 \cdot \Omega\quad DCV = 12 \cdot V\quad T_1 = 15 \cdot K\quad Vol = 3 \cdot L\quad \rho = 1 \frac{kg}{L}\quad C_p = 4180 \cdot \frac{J}{kg \cdot K}\]

\[t = 17.5 \cdot \text{min}\]

\[T_2 = \frac{DCV^2}{R \cdot t + \rho \cdot Vol \cdot C_p \cdot T_1} = 15.402 \cdot K\]

Problem 16
(5 points) In the process of climbing Mt. Everest, you are at an elevation of 28,500 feet struggling to reach the summit at 29,035 ft. As hypothermia begins to set in, you pull out your 200W fishtank heater and a battery pack with eight AA batteries arranged in series (1.5 volts each).

You weigh 150 lbs, and your average specific heat is 3470 \(\frac{J}{kg \cdot °C}\). If your body generates enough heat to exactly account for heat loss to the environment and these are REALLY good batteries that won’t run out of power, then the time required for the temperature of your body to rise by 1 °C is closest to . . .

e. 32,800 s

\[\text{mass} = \frac{150 \cdot \text{bf}}{g} = 68.039 \quad \text{kg}\quad C_p = 3470 \cdot \frac{J}{kg \cdot K}\quad \Delta T = 1 \cdot K\quad R = 20 \cdot \Omega\quad DCV = 12 \cdot V\]

\[t = \frac{\text{mass} \cdot C_p \cdot \Delta T \cdot R}{DCV^2} = 32790.9 \quad \text{s}\]
Problem 17
(5 points) Each of the 1.5 million engineers in the USA decide to power up a 2003 fishtank heaters in a symbol of unity for the beauty of science. Each engineer makes a pilgrimage to Ruston to place their heater in the Lady of the Mist water fountain. Knowing that this is a lot of heaters, President Gulce wisely decides to expand the fountain to a diameter of 10m with a water depth of 1m. The heaters are then uniformly placed in the water (adding the heaters causes the water to rise, but the volume of the water doesn’t change). If all heaters are turned on simultaneously, the time required to increase the temperature of the water to 99°C is closest to . . .

- Heaters weigh 50 grams and with an average specific heat of 910 \( \frac{J}{kg\cdot ^\circ C} \)
- Initial temperature of water and heaters is 15°C
- Resistance of each heater is 20Ω and is powered by 12VDC

\[
\begin{align*}
\alpha & \text{ 1.1 s} \\
\beta & \text{ 2.5 s} \\
\gamma & \text{ 11.1 s} \\
\delta & \text{ 45.8 s} \\
\epsilon & \text{ 136 s} \\
\zeta & \text{ 285 s} \\
\eta & \text{ 757 s} \\
\iota & \text{ 1023 s} \\
\varphi & \text{ 3084 s}
\end{align*}
\]

Problem 18
RTD-related
RTD MEDIUM
(5 points) An RTD made of nickel has a resistance of 124.5Ω. If the nickel pattern is 0.2 micrometers thick, 20.75 cm long, and has a resistivity of 1.2 x 10⁻⁷ Ω-m, then (assuming a rectangular cross-section) the width of the nickel trace is closest to . . .

\[
\begin{align*}
\alpha & \text{ 0.125 mm} \\
\beta & \text{ 0.25 mm} \\
\gamma & \text{ 0.5 mm} \\
\delta & \text{ 1.0 mm} \\
\epsilon & \text{ 2.0 mm} \\
\zeta & \text{ 5 mm} \\
\eta & \text{ 10 mm} \\
\iota & \text{ 50 mm}
\end{align*}
\]

Answer: D 1.0 mm
Problem 19
RTD Given Geometry
(5 points) Someone in your group designed an RTD, but you are not sure what resistance it is. The RTD pattern is shown here, where \( L = 1.5 \) cm, and \( S = 1 \) cm (all sides of the diamond shape are 5 centimeters long). This RTD is made from a material with a resistivity of \( 1.2 \times 10^{-7} \, \Omega \cdot \text{m} \). The thickness of this material is 0.2 microns, with a line width of 0.5 mm. The resistance of this RTD is closest to:

a. 3 Ohm
b. 6 Ohm
c. 12 Ohm
d. 24 Ohm
e. 48 Ohm
f. 96 Ohm
g. 192 Ohm
h. 384 Ohm

\[
R = 2R_1 + \frac{1}{R_2 + \frac{1}{R_2}} = 2R_1 + \frac{1}{\frac{2}{R_2}} = 2R_1 + \frac{2}{2}R_2
\]

\[
R_1 = \frac{\rho L}{A} = \frac{1.2 \times 10^{-7} \, \text{m} \cdot (0.015)}{0.2 \times 10^{-4} \, \text{m} \cdot 0.0005 \, \text{m}} = 18 \, \Omega
\]

\[
R_2 = \frac{\rho L}{A} = \frac{1.2 \times 10^{-7} \, \text{m} \cdot (0.02)}{0.2 \times 10^{-4} \, \text{m} \cdot 0.0005 \, \text{m}} = 24 \, \Omega
\]

\[
R = 2(18 \, \Omega) + \frac{24 \, \Omega}{2} = 48 \, \Omega
\]

ANSWER: E 48 Ohm

Problem 20
(5 points) A well-insulated container holds 15 liters of water which have an initial temperature of 21°C. A 2570 gram block of unknown material with a temperature of 98°C is added to the container, the lid is closed, and the system reaches an equilibrium temperature of 28°C. The specific heat capacity value for the block of material is closest to:

a. 2440 \, J/\,\text{kg}°C
b. 2550 \, J/\,\text{kg}°C
c. 2660 \, J/\,\text{kg}°C
d. 2770 \, J/\,\text{kg}°C
e. 2880 \, J/\,\text{kg}°C
f. 2990 \, J/\,\text{kg}°C
g. 3110 \, J/\,\text{kg}°C
h. 3220 \, J/\,\text{kg}°C
i. 3330 \, J/\,\text{kg}°C
j. 3440 \, J/\,\text{kg}°C

Answer: a
Problem 21
(5 points) Dr. Moller is trying to protect his alligator from harsh Ruston winters. He sets up a glass (C_p = 840 J/kg°C, \( \rho = 2800\text{ kg/m}^3 \)) water tank that is heated with 1.9 mm diameter Nichrome wire (\( \rho = 1.5 \times 10^5 \Omega \cdot \text{m} \)) powered by a 220V source, and insulated with polystyrene foam. The tank’s inside dimensions are 3m x 2m x 1.5m, and the glass walls and floor are 2cm thick. Dr. Moller accidentally turns on the heater before he puts water in the tank, and the glass walls and floor reach a temperature of 88°C. Fortunately he notices, and adds 19°C water, filling the tank to a line 10cm below the top of the tank. After 45 more minutes with the heater on, the water and the glass reach a temperature of 21°C. The number of wraps of the heater wire around the glass water tank is closest to: (Notes: Assume zero heat loss from the tank, and uniform temperatures inside the insulation at the end of the 45 minutes. Also assume that the insulation absorbs negligible amount of thermal energy.)

Answer: f

Problem 22
(5 points) You have decided to open a pancake restaurant. Your secret pancake recipe calls for 3.4% by weight vanilla extract for the pancake batter. If you have 25 lbs of uncooked pancake batter with 1.3% by weight vanilla extract, the amount of vanilla extract that you need to add to match your recipe is closest to...

Answer: f
Problem 23
(5 points) An unknown amount of saltwater (1% by weight NaCl), 20 lbs of ice and 1 lb of dry salt were combined in a large container. If the salinity was determined to be 2.2% by weight NaCl after the ice of the mixture melted, the final mass of the solution in the container is closest to...

(Assume the density of water, regardless of temperature, is 1kg/l)

Answer: a

Problem 24
(5 points) Given the information below (note: percentages are % weight in water), the mass of Z is closest to...

Answer = a

Be careful on fractions vs percents!!!