1A) The dimensions of the swimming pool (4x3x4) show that the area of the pool is 12 m² with a depth of 4 m. When we apply 30 m³ water on a 12 m² area, the depth of the water in the swimming pool will be 2.5 meter (30/12 = 2.5).

To obtain a net force of zero on the membranes at the pool/manometer interface, pressures on the left and right side of the membranes need to be equal.

The pressure created by the 2.5 m water column on the bottom of the pool is calculated as

\[ p = h \cdot \gamma = h \cdot \rho \cdot g \]

\[ p = 2.5 \text{ m} \cdot 1000 \text{ kg/m}^3 \cdot 9.8 \text{ m/s}^2 = 24,500 \text{ N/m}^2 \]

Manometer A is filled with water. To create the same pressure with the column of water, we need the same calculation:

\[ 24,500 = h \cdot 1000 \cdot 9.8 \]

\[ h = 2.5 \text{ m} \]

which is the height of the water in the manometer as calculated from the bottom of the pool, or \( h_a = 2.5 \text{ m} = 250 \text{ cm} \).

Pressure on the membrane of manometer B is only 1.5 m of water, since the membrane is 1 meter above the bottom of the pool.

\[ p = h \cdot \gamma = h \cdot \rho \cdot g \]

\[ p = 1.5 \text{ m} \cdot 1000 \text{ kg/m}^3 \cdot 9.8 \text{ m/s}^2 = 14,700 \text{ N/m}^2 \]

To calculate the height of the mercury we set the pressures equal:

\[ 14,700 = h \cdot 13,600 \cdot 9.8 \]

\[ h_b = 0.11 \text{ m} = 11 \text{ cm} \]

1B) The pressure was calculated in N/m², and we need to convert this to psi. Back of the book shows that 1 N/m² = 0.145*10³ psi.

Pressure created by fluid in manometer A = 24500*0.145*10³ = 3,55 psi
Pressure created by fluid in manometer B = 14,700*0.145*10³ = 2,13 psi
The pressure of manometer B is less, because there is 1 meter less water above the membrane in the pool.

1C) A volume of 0.6 m$^3$ of mercury on the area of 12 m$^2$ = 0.05 m of mercury. This is the heaviest fluid and will lay on the bottom of the pool.

A volume of 12 m$^3$ of oil on an area of 12 m$^2$ = 1 m of oil. Since this is the lightest fluid, it will flow on top of the water. The scientist’s pool will look now like:

The pressure on the membrane of manometer A is now:

$$p = (0.05 \times 13,600 \times 9.8) + (2.5 \times 1000 \times 9.8) + (1.0 \times 850 \times 9.8)$$

$$p = 39.394 \text{ kN/m}^2$$

The pressure on membrane B is now:

$$p = (1.55 \times 1000 \times 9.8) + (1.0 \times 850 \times 9.8)$$

$$p = 23.52 \text{ kN/m}^2$$

Height in manometer A is thus:
39.394 = h * 1000 * 9.8

\[ h_B = 4.02 \text{ m} = 402 \text{ cm} \]

Height in manometer B is thus:

\[ 23,520 = h * 13600 * 9.8 \]

\[ h_B = 0.176 = 17.6 \text{ cm} \]

2A) To draw the Thiessen polygons, draw a line between two weather stations, divide this line exactly in half, and draw the line perpendicular to this. In the case below, this will result in the total area divided into four equal sections. Taking the normal average (add all four data and divide by four) and the average calculated with the Thiessen polygons (multiply each data by 0.25 and add all up) does not make any difference in this case. With the low number of stations that are in this watershed, isohyetal lines would probably not be very useful.

![Thiessen Polygons](image)

2B) Since the sprinkler application rate (also known as rainfall intensity) is 1 cm/hr, the storm from part A must have had a duration of 3 hours. The UHG therefore is a 1 unit hydrograph for a 3 hour application (This unit hydrograph was developed based on the 3 cm applied in 3 hours. The total area under the graph was divided by 3 to obtain 1 unit under the area of the hydrograph).

To create a hydrograph for a 6 hour application, we know that we can add two unit hydrographs together, where the second hydrograph is shifted 3 hours. The total area under the summation graph will now be 2 units (Figure 3) (1 unit from the first
hydrograph and 1 unit from the second) and must be divided by 2 to obtain the 6 hour 1 unit hydrograph.

Figure 3: Six hour 2 unit hydrograph

Since the actual storm had 6 mm applied, with 16.7% stored, the actual runoff from the field was only 5 cm. To obtain a hydrograph for a 5 cm runoff event, we multiply the 1 unit 6 hour hydrograph by 5 to obtain the hydrograph for this irrigation event.

Dividing the peak (1/3) by 2 to obtain the UHG and multiplying by 5 to obtain the runoff of the 6 hour irrigation event creates a new peak at a value of 5/6.
3)

\[ E_{\text{pan}} = 250 \text{ mm} \]
\[ E_{\text{take}} = 0.7 \times E_{\text{pan}} \] (0.7 was given in class or can be found in the Grismer book on page 86)

Using given data and table, \( C_p \) to convert \( E_{\text{pan}} \) into \( E_{\text{c}} \) can be found as 0.55

\[ E_{\text{c}} = 0.55 \times E_{\text{pan}} \]

However, we are looking for \( E_{\text{c}} \)

\[ E_{\text{c}} = K_c \times E_{\text{c}} = 0.6 \times 0.55 \times E_{\text{pan}} \]

\[ E_{\text{take}} = 0.7 \times 250 \text{ mm} = 175 \text{ mm} \]
\[ E_{\text{c}} = 0.6 \times 0.55 \times 250 = 82.5 \text{ mm} \]

Since this is a water balance problem:

\[ \Sigma \text{In} - \Sigma \text{Out} = \Delta S/\Delta t \]

Precipitation - \( E_{\text{take}} - E_{\text{c}} - Q_R = \Delta S/\Delta t \)

Ppt is obtained by adding all values from the graph (Figure 4) for 1 year.

Since the different values are for different areas, it is better to continue calculations in volume:

\[ 0.430 \text{ m}^2 \times 40,000 \text{ m}^2 - 0.175 \text{ m}^2 \times 10,000 \text{ m}^2 - 0.0825 \text{ m}^2 \times 30,000 \text{ m}^2 - Q_R = -0.5\text{ m}^2 \times 10,000 \text{ m}^2 \]

\[ 17200 - 1750 - 2475 - Q_R = -5000 \text{ m}^3 \]

\[ Q_R = 17975 \text{ m}^3 \]

1 \text{ m}^3 = 1000 \text{ liters} \Rightarrow Q_R = 17,975,000 \text{ L/year} \]

1 \text{ year} = 365 \times 24 \times 3600 \text{ seconds}

\[ Q_R = 0.57 \text{ L/s} \]
4A) To keep the net forces on the membranes zero, would the scientist have to add or subtract fluids from the manometers?

Although the density of ice is lower than water, the total mass of water in the pool will stay the same. When water freezes into ice, ice will expand, or, the layer of ice in the pool will be thicker than the layer of water that went into the ice. However, since the density of ice is lower than that of water, the total mass pushing down on the membranes will still be the same, and there is no change necessary for the manometer fluids.

4B) The heat of fusion is 80 cal/g. 1 cal = 4.18 J/g.

402 * 10^6 Joules are released. This would freeze an amount of

\[ 402 \times 10^6 \div (80 \times 4.18) = 1.2 \times 10^6 \text{ gram} \]

The density of ice is 0.92 g/cm^3, which results in a volume of ice of

\[ 1.2 \times 10^6 \div 0.92 = 1.3067 \times 10^6 \text{ cm}^3 \]

The pool has a surface area of 300 x 400 cm = 120,000 cm^2

The depth of the layer of ice will therefore be:

\[ 1.3067 \times 10^6 \div 1.2 \times 10^3 = 10.9 \text{ cm} \]