PROBLEM #1:  
GIVEN:  
- Grain size distributions from seven (7) suppliers shown in Figure A and given in .CSV file on website.  
- D4318 Testing Results: ML or MH silts.

REQUIRED:  
- Determine the USCS classification and coefficient of permeability for each soil sample.  
- Comment on any appreciable difference between these soils in terms of coefficient of permeability.  
- Comment on any appreciable difference between these soils based on the USCS.
SOLUTION:

Soil Classification:

Table A. USCS Classification Summary (using data from Figure A, the provided .csv file, and ASTM D2487).

<table>
<thead>
<tr>
<th>Pit</th>
<th>% Fines</th>
<th>% Gravel</th>
<th>D_{10} (mm)</th>
<th>D_{30} (mm)</th>
<th>D_{60} (mm)</th>
<th>C_c</th>
<th>C_u</th>
<th>USCS Symbol</th>
<th>USCS Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>5</td>
<td>16</td>
<td>0.125</td>
<td>0.28</td>
<td>0.62</td>
<td>1.01</td>
<td>4.96</td>
<td>SP-SM</td>
<td>Poorly Graded Sand with Silt and Gravel</td>
</tr>
<tr>
<td>#2</td>
<td>6</td>
<td>2</td>
<td>0.110</td>
<td>0.24</td>
<td>0.46</td>
<td>1.14</td>
<td>4.18</td>
<td>SP-SM</td>
<td>Poorly Graded Sand with Silt</td>
</tr>
<tr>
<td>#3</td>
<td>0</td>
<td>3</td>
<td>0.300</td>
<td>0.46</td>
<td>0.54</td>
<td>1.31</td>
<td>1.80</td>
<td>SP</td>
<td>Poorly Graded Sand</td>
</tr>
<tr>
<td>#4</td>
<td>6</td>
<td>13</td>
<td>0.115</td>
<td>0.27</td>
<td>0.54</td>
<td>1.17</td>
<td>4.70</td>
<td>SP-SM</td>
<td>Poorly Graded Sand with Silt</td>
</tr>
<tr>
<td>#5</td>
<td>6</td>
<td>3</td>
<td>0.110</td>
<td>0.24</td>
<td>0.46</td>
<td>1.14</td>
<td>4.18</td>
<td>SP-SM</td>
<td>Poorly Graded Sand with Silt</td>
</tr>
<tr>
<td>#6</td>
<td>2</td>
<td>0</td>
<td>0.180</td>
<td>0.32</td>
<td>0.46</td>
<td>1.24</td>
<td>2.56</td>
<td>SP</td>
<td>Poorly Graded Sand</td>
</tr>
<tr>
<td>#7</td>
<td>5</td>
<td>7</td>
<td>0.150</td>
<td>0.42</td>
<td>0.80</td>
<td>1.47</td>
<td>5.33</td>
<td>SP-SM</td>
<td>Poorly Graded Sand with Silt</td>
</tr>
</tbody>
</table>

Since C_u is less than 6 for all the soils, the soils are poorly graded (see Figure 3 from ASTM D2487, provided in Figure B). Soils with 5% or greater fines are SP-SM (Poorly Graded Sand with Silt) with the noted exception of Pit #1, which is a SP-SM (Poorly Graded Sand with Silt and Gravel) due to having 16% gravel (i.e. % retained by #4 sieve).

Coefficient of Permeability (k):

Use Hazen (1930) empirical formula relating effective grain size ($D_{10}$) to coefficient of permeability:

$$k (cm/\text{sec}) = c D_{10}^2$$

Where $c = 1$ to 1.5.

Table B presents a summary of calculated $k$ values using the effective diameter ($D_{10}$) from the grain size analysis and Hazen’s formula.
Figure B. USCS Soil Classification Figure 3 of ASTM D2487.

Table B. Summary of calculated $k$ values using $D_{10}$.

<table>
<thead>
<tr>
<th>Pit No.</th>
<th>$D_{10}$ (mm)</th>
<th>$k$ (cm/sec) $c=1$</th>
<th>$k$ (cm/sec) $c=1.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.125</td>
<td>0.016</td>
<td>0.023</td>
</tr>
<tr>
<td>2</td>
<td>0.110</td>
<td>0.012</td>
<td>0.018</td>
</tr>
<tr>
<td>3</td>
<td>0.300</td>
<td>0.090</td>
<td>0.135</td>
</tr>
<tr>
<td>4</td>
<td>0.115</td>
<td>0.013</td>
<td>0.020</td>
</tr>
<tr>
<td>5</td>
<td>0.110</td>
<td>0.012</td>
<td>0.018</td>
</tr>
<tr>
<td>6</td>
<td>0.180</td>
<td>0.032</td>
<td>0.049</td>
</tr>
<tr>
<td>7</td>
<td>0.150</td>
<td>0.023</td>
<td>0.034</td>
</tr>
</tbody>
</table>

Look at the calculated coefficients of permeability graphically with typical range of $k$ values for various soils from Lecture Notes in Figure C.
Figure C. Ranges of calculated $k$ values with respect to general ranges of $k$ for different soils.

From examination of Figure A, the soil samples are all primarily medium to fine sands (medium sands are from #10 to #40 sieves, fine sands are from #40 to #200 sieves). As shown above, these sands fit mainly towards the low end of the range for coarse sands. This makes sense, since medium sands are between coarse and fine in grain size. Notice the soil sample from Pit #3. It has less fines and a significantly greater effective size ($D_{10}$) than the other pit samples, which correlates to a greater $k$ value by almost 1 order of magnitude.

NOTE: These sands are all from the same geologic deposits in Carver, MA. All have similar grain size distributions, soil classifications, and calculated $k$ values (with the noted exception of Pit #3).
**PROBLEM #2:**

**GIVEN:**

Constant head permeability test results:

Length of Sample (L) = 8 inches  
Sample Diameter (cylindrical sample) = 1.5 inches  
Constant Head Difference = 3 feet  
Volume of Water Collected in 6 minutes: 18 cubic inches  
Soil USCS Classification: SM

**REQUIRED:**

- Determine the coefficient of permeability for the tested soil.
- Does the calculated coefficient of permeability match the expected results from the soil classification?

**SOLUTION:**

For constant head permeability test:

\[ k = \frac{QL}{Aht} \]

Where:

- \( Q \) = Quantity of water collected over time  
  \( t \) = 6 minutes  
  \( L = 8 \text{ inches} = 0.67 \text{ ft} \)

- \( A \) = Area of Sample  
  \( A = \pi (radius)^2 = \pi (0.75 \text{ inches})^2 = 1.767 \text{ in}^2 = 0.0123 \text{ ft}^2 \)

- \( h \) = Constant head difference  
  \( h = 3 \text{ ft} \)

\[ k = \frac{(0.0104 \text{ ft}^3)(0.67 \text{ ft})}{(0.0123 \text{ ft}^2)(3 \text{ ft})(6 \text{ min})} = 0.031 \text{ ft} / \text{ min} \]

\[ k = 0.031 \text{ ft/min} = 0.0157 \text{ cm/sec} = 0.0062 \text{ in/sec}. \]

The results of the constant head test are compared to typical ranges of \( k \) for soils as shown in Figure D. As shown in Figure D, the range of \( k \) calculated from the constant head test falls within the clean sands range and not for sand, silt, and clay mixtures. Therefore, this is **not** a reasonable for a SM soil.
Figure D. Constant Head $k$ Test Results compared to typical Soil $k$ Values (after Casagrande and Fadum (1940) and Terzaghi et al. (1996).
PROBLEM #3:
GIVEN:
• Figure 2. The coarse grain soil layer is from Pit #7 in Problem #1.

**Figure 2.** Information for Problem #3 (NTS).

REQUIRED:
• Determine the hydraulic gradient and rate of flow per time through the coarse grain soil layer.

**SOLUTION:**

\[ i = \frac{\Delta h}{L} = \frac{17.5 \text{ ft}}{525 \text{ ft} \cos 12^\circ} = 0.0326 = 0.033 \]

\[ i = 0.033 \]

Remember: \( L = \) Length of Water Flow, not horizontal distance!

For low end of calculated \( k \) for Pit #7 (0.023 cm/sec = 0.045 ft/min):
\[ q = k_i A = \left(0.045 \frac{ft}{min}\right) \left(0.033\right) \left(12.5 \ ft\right) \left(\cos 12^\circ\right) \left(1 \ ft\right) \]

\[ q = 0.0182 \ ft^3/min/ft \]

\[ q = 1.09 \ ft^3/hr/ft \]

\[ q = 26.1 \ ft^3/day/ft \]

For high end of calculated \( k \) for Pit #7 (0.034 cm/sec = 0.067 ft/min):

\[ q = k_i A = \left(0.067 \frac{ft}{min}\right) \left(0.033\right) \left(12.5 \ ft\right) \left(\cos 12^\circ\right) \left(1 \ ft\right) \]

\[ q = 0.027 \ ft^3/min/ft \]

\[ q = 1.62 \ ft^3/hr/ft \]

\[ q = 38.9 \ ft^3/day/ft \]

**ANSWER SUMMARY:**

\( i = 0.033 \)

\( q_{low} = 26.1 \ ft^3/day/ft \)

\( q_{high} = 38.9 \ ft^3/day/ft \)
PROBLEM #4:
GIVEN:
- Flow net provided in Figure 3.
- Soil is homogeneous, isotropic sand (i.e. \( k_x = k_z \)) with a coefficient of permeability of \( 1.0 \times 10^{-1} \) cm/sec. The sand overlies a relatively impervious layer (i.e. solid bedrock).

REQUIRED:
- Determine the total rate of seepage per unit length of the sheet pile wall (ft\(^3\)/day/ft). Briefly explain why you might need to calculate this value.
- Calculate the water pressure at points 1 through 12 (see Figure 3). Plot the water pressure distribution on both sides of the sheet pile wall.
- Determine the pore pressure \((u)\) at points A, B, C, and D. Scale the drawing within the soil mass to determine the elevations of Point C and D.
**SOLUTION:**

\[ q = \text{seepage loss} = k \frac{HN_f}{N_d} \]

Where:

- \( K = \text{Coefficient of permeability} = 0.1 \text{ cm/sec} = 283 \text{ ft/day} \)
- \( H = \text{Head Difference} = 15 \text{ ft} \)
- \( N_f = \text{Number of Flow Channels} = 4 \)
- \( N_d = \text{Number of Drops} = 10 \)

\[ q = k \frac{HN_f}{N_d} = (283 \text{ ft/day})(15 \text{ ft}) \left( \frac{4}{10} \right)(1 \text{ ft}) = 1698 \text{ ft}^3 \text{/day/ft} \]

\( q = 1698 \text{ ft}^3 \text{/day/ft} \). You would need this value in order to properly size dewatering equipment for the “right” side.

Potential Drop per Equipotential Line = \( H/N_d = 15\text{ft}/10 = 1.5\text{ft} \)

Table C presents a summary of the total head elevations of each point based on known elevations and potential drop per equipotential line. Height of water (\( h_w \)) is (total head elevation – point elevation). Pore pressure (\( u \)) is \( h_w \gamma_w \). See Figure E for Pore Pressure (\( u \)) with respect to Elevation for Points 1-12.

**Table C.** Summary of Total Head and Pore Pressure calculations along Sheet Pile.

<table>
<thead>
<tr>
<th>Point</th>
<th>Point Elevation (ft)</th>
<th>Total Head Elevation (ft)</th>
<th>Height of Water (ft)</th>
<th>( u ) (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>108</td>
<td>108.0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>93</td>
<td>108.0</td>
<td>15.0</td>
<td>936</td>
</tr>
<tr>
<td>3</td>
<td>91.4</td>
<td>106.5</td>
<td>15.1</td>
<td>942</td>
</tr>
<tr>
<td>4</td>
<td>89.4</td>
<td>105.0</td>
<td>15.6</td>
<td>973</td>
</tr>
<tr>
<td>5</td>
<td>87.4</td>
<td>103.5</td>
<td>16.1</td>
<td>1005</td>
</tr>
<tr>
<td>6</td>
<td>86.3</td>
<td>102.0</td>
<td>15.7</td>
<td>980</td>
</tr>
<tr>
<td>7</td>
<td>86</td>
<td>100.5</td>
<td>14.5</td>
<td>905</td>
</tr>
<tr>
<td>8</td>
<td>86.3</td>
<td>99.0</td>
<td>12.7</td>
<td>792</td>
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<tr>
<td>9</td>
<td>87.4</td>
<td>97.5</td>
<td>10.1</td>
<td>630</td>
</tr>
<tr>
<td>10</td>
<td>89.4</td>
<td>96.0</td>
<td>6.6</td>
<td>412</td>
</tr>
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<td>11</td>
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<td>94.5</td>
<td>3.1</td>
<td>193</td>
</tr>
<tr>
<td>12</td>
<td>93</td>
<td>93.0</td>
<td>0.0</td>
<td>0</td>
</tr>
</tbody>
</table>
Use same methodology to determine pore pressure at Points A, B, C, and D. Determine elevations of Points C and D by scaling drawing. A summary is presented in Table D.

**Table D.** Summary of Total Head and Pore Pressure calculations at Points A – D.

<table>
<thead>
<tr>
<th>Point</th>
<th>Point Elevation (ft)</th>
<th>Total Head Elevation (ft)</th>
<th>Height of Water (ft)</th>
<th>$u$ (psf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>84.6</td>
<td>103.5</td>
<td>18.9</td>
<td>1179</td>
</tr>
<tr>
<td>B</td>
<td>80</td>
<td>99</td>
<td>19</td>
<td>1186</td>
</tr>
<tr>
<td>C</td>
<td>87.2</td>
<td>96.0</td>
<td>8.8</td>
<td>549</td>
</tr>
<tr>
<td>D</td>
<td>84.9</td>
<td>98.3</td>
<td>13.4</td>
<td>833</td>
</tr>
</tbody>
</table>