Rig Math
The Calculator and Main Keyboard

- **Numerical 10-key pad** – used for entering numerical values
- **Power On Switch**
- **Power Off Switch**
- **Display**
- **Basic Math Operations**
- **Equal Key** – Resolves operations
- **Trigonometric Functions** – These keys will be used where wellbore angle is an issue

These are the keys that will be used for basic calculations.
The 2nd Keyboard and Accessing the 2nd Keyboard

The 2nd keyboard is turned by pressing the 2nd key. All 2nd keyboard functions are in blue and are located above the keys of the main keyboard.

2nd Key

Your instructor will guide you in using the second keyboard and related functions as they are needed.
“Fixing” The Display

Fixing the display means to tell the calculator how many decimal points are to be displayed with each calculation. The factory default setting for the calculator is to display calculations in 9 decimal points. Not only is this a bit cumbersome to read but is also not practical for the calculations to be done in this course.

How To Assign The Number of Decimal Points

To fix the display the 2nd keyboard must be accessed. Press the 2nd key to turn on the 2nd keyboard. Just above the decimal point you’ll see the word FIX. Press this key.

At right is the display after selecting FIX.

Use the RIGHT ARROW KEY

Press this key to select the number of decimal points you want to appear in the display.

Once you have the cursor under your selection press the ENTER key. The calculator then leaves the 2nd keyboard and returns to the main keyboard.
Addition

#1  88 + 109 = _________
#2  1189.96 + 23.87 = _________
#3  252311 + 19855 = _________
#4  23.674 + 11000032 = _________

The addition key \( + \) is used between the two numbers that are to be added. Follow this with the ENTER key.

You’ll notice that the numbers you entered along with the answer appear in the display.

Subtraction

#1  188 – 139.87 = _________
#2  553833 – 358127 = _________
#3  .8786 – .5491 = _________
#4  38.33 – 35.8127 = _________

The subtraction key \( - \) is used between the two numbers that are to be subtracted. Followed by the ENTER key.

You’ll notice that the numbers you entered along with the answer appear in the display.
# Rig Math

## Multiplication

<table>
<thead>
<tr>
<th>#</th>
<th>Equation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$55 \times 3.5$</td>
<td>$______$</td>
</tr>
<tr>
<td>2</td>
<td>$553833 \times .8$</td>
<td>$______$</td>
</tr>
<tr>
<td>3</td>
<td>$.8865 \times 78.81$</td>
<td>$______$</td>
</tr>
<tr>
<td>4</td>
<td>$42 \times 1.35$</td>
<td>$______$</td>
</tr>
</tbody>
</table>

## Division

<table>
<thead>
<tr>
<th>#</th>
<th>Equation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$5.543 \div 3.82$</td>
<td>$______$</td>
</tr>
<tr>
<td>2</td>
<td>$24.87 \div 16.19$</td>
<td>$______$</td>
</tr>
<tr>
<td>3</td>
<td>$553.875 \div .9855$</td>
<td>$______$</td>
</tr>
<tr>
<td>4</td>
<td>$2.375 \div 2.5$</td>
<td>$______$</td>
</tr>
</tbody>
</table>

The multiplication key $\times$ is used between the two numbers that are to be added. Followed by the **ENTER** key.

You’ll notice that the numbers you entered along with the answer appear in the display.

The division $\div$ key is used between the two numbers that are to be divided. Follow this with the **ENTER** key.

You’ll notice that the numbers you entered along with the answer appear in the display.

Division will appear this way in the display.

$$5.543/3.82$$
Correcting Entry Mistakes

If you enter a wrong number, it can be corrected without having to clear everything that’s been entered, especially if you’re working with a large formula or lengthy calculation.

**For example:** you want to enter the number 8.755 but instead you enter 8.577. This can be easily corrected by using the **Left Arrow** key.

Press the **LEFT ARROW** Key until the cursor is over the mistake. With the cursor in the correct place, simply reenter the correct number.
Correcting Entry Mistakes

Another means of correcting a mistake is to use the **DELETE** and **INSERT** keys.

Place the cursor over the mistake and press the **DELETE** key until the mistake is erased.

Then press the **2nd** key to activate the **INSERT** function, since this is on the **2nd** keyboard.

Insert the number you want to appear in the display and then press the **ENTER** key.
Converting Fractions to Decimals

These are all common fractions. And when these are encountered and are part of a calculation, they have to be converted to a decimal form. This is done by performing the operation they represent, which is *division*. The top number, called the *numerator* is divided by the bottom number known as the *denominator*.

If the fraction is one that is used in conjunction with a whole number, then the fraction is converted to decimal form and added to the whole number.

For example: 9 5/8” casing is a common size. But there are cases where we have to know the OD in terms of decimal.

Another example:

\[
\begin{align*}
\frac{1}{2} &= \text{________} \\
\frac{3}{8} &= \text{________} \\
\frac{5}{8} &= \text{________} \\
9 \frac{5}{8} \ Csg &= 9 + \frac{5}{8} = \\
9.625 + .625 &= 9.625 \\
2 \frac{7}{8}'' \ Tbg &= 2 + \frac{7}{8} = \\
2 + .875 &= 2.875
\end{align*}
\]
Exponentiation - Squaring

$X^2$ .... or better known as squaring....
To square a number (multiplying the number by itself), enter the number and then press the $X^2$.

#1 $3.5^2 = \underline{}$

#2 $12.25^2 = \underline{}$

#3 $4.5^2 = \underline{}$

#4 $125.02^2 = \underline{}$
Exponentiation – Powers Greater Than 2

If a number is to be raised to a power greater than 2 the SPECIFIC POWER key is used. ▲

Enter the main number
Press the SPECIFIC POWER key
Enter the numerical power

#1 \[3.5^3 = \]

#2 \[364^4 = \]

#3 \[17.23^5 = \]

#4 \[12.25^5 = \]

#5 \[1.86^3 = \]
Exponentiation – Fractional Exponents

Raising numbers to fractional powers is done by:

Enter the main number
Press the **SPECIFIC POWER** key
Enter the exponent

\[
\begin{array}{c}
\text{#1} \quad 24^{1.08} = \underline{} \\
\text{#2} \quad 17.5^{1.25} = \underline{} \\
\text{#3} \quad 101.75^{0.325} = \underline{} \\
\text{#4} \quad 420^{1.885} = \underline{} \\
\text{#5} \quad 0.7856^{3.887} = \underline{} \\
\end{array}
\]

Courtesy of Texas Instruments
Obtaining The Square Root

To get the SQUARE ROOT of a number:

Press the 2nd key

Press the SQUARE ROOT key – a set of parentheses will open

Enter the number and then press the CLOSE PARENTHESE key

#1 \( \sqrt{78.56} = \) _________

#2 \( \sqrt{8.755} = \) _________

#3 \( \sqrt{8965437} = \) _________

#4 \( \sqrt{12.7843} = \) _________

#5 \( \sqrt{10829564} = \) _________
Parentheses surround and resolve individual operations such as addition, multiplication, subtraction and division. They work in “pairs.” Using the parentheses eliminates a great deal of recording the results of individual operations.

**Examples**

#1 \((32.5 + 11) \times 10 = \) \[
\]

#2 \(\left(\frac{14.7}{11.9}\right) \times 800 = \) \[
\]

#3 \(\frac{(65.4 - 17.2)}{65.4} = \) \[
\]

#4 \(\frac{(5^2 - 4.276)}{1029} = \) \[
\]
Examples

#1 \[
\left( \frac{8.5^2 - 5^2}{1029} \right) \times 5000 = \quad
\]

#2 \[
\left( \frac{4.5 \times 42}{2.45 \times (8.5^2 - 5^2)} \right) = \quad
\]

#3 \[
\left( \frac{3.4 \times 16 \times 4800}{1000 \times (8.5 - 5)^2} \right) + \left( \frac{14 \times 4800}{200 \times (8.5 - 5)} \right) = \quad
\]

#4 \[
2.45 \times \sqrt{\left( \frac{1325 \times 0.78}{312} \right)} \times 3.78 = \quad
\]
Accurate Drill Collar Weight

Non-Spiraled Collars

The weight on pounds per foot and total weight of a drill collar can be calculated by knowing the OD, the ID, and the length of the drill collar. The following two formulas are used to determine this.

\[ \left( \frac{OD^2 - ID^2}{1029.4} \right) \times 2748 = Weight_{#/ft} \]

\[ Weight_{#/ft} \times Length_{Feet} = Total Weight \]

Use the two formulas above and the information given below to calculate the weight in pounds per foot and the total weight for these drill collars.

**Examples:**

<table>
<thead>
<tr>
<th>Drill Collar Dimensions</th>
<th>Weight #/ft</th>
<th>Total Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>9” OD, 3 ¼” ID, 90’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 ¾” OD, 2 ½” ID, 180’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 ¾” OD, 3” ID, 270’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 1/8” OD, 1 7/8” ID, 360’</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Spiraled Collars

When drill collars are machined with a spiral OD, some of the weight is lost; actually about 4% of the total weight is machined off. So the collar weighs approximately 96% of its original weight. The following formula can be used to estimate the weight of a spiraled drill collar in pounds per foot. Once the weight per foot is calculated and the length is known, the total weight of the drill collar can be determined. Calculate the “per foot” weight and the total weight for the following drill collars.

\[
\left( \frac{OD^2 - ID^2}{1029.4} \right) \times 2748 \times .96 = \text{Weight 
#/Ft}
\]

Examples:

| Drill Collar Dimensions | Weight 
#/ft | Total Weight |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9” OD, 3 ¼” ID, 90’</td>
<td>_______</td>
<td>___________</td>
</tr>
<tr>
<td>6 ¾” OD, 2 ½” ID, 180’</td>
<td>_______</td>
<td>___________</td>
</tr>
<tr>
<td>7 ¾” OD, 3” ID, 270’</td>
<td>_______</td>
<td>___________</td>
</tr>
<tr>
<td>5 1/8” OD, 1 7/8” ID, 360’</td>
<td>_______</td>
<td>___________</td>
</tr>
</tbody>
</table>
Buoyancy

Buoyancy is a property of a liquid to support a portion or all of the weight of an object immersed in the liquid. The more dense the liquid is, the more buoyant it is. For example, it’s easier to swim in salt water than fresh water due to the higher density of salt water. An object in salt water weighs less than it does in fresh water. The following formula is used to determine the buoyant effect, or better known as the **Buoyancy Factor** for steel immersed in drilling mud.

\[
\frac{(65.4 - \text{Mud Weight}_{ppg})}{65.4} = \text{Buoyancy Factor}
\]

**Example:**

Use the formula above to calculate the buoyancy factors for the following mud weights.

- 8.8 ppg \( \underline{\text{BF}} \)
- 9.2 ppg \( \underline{\text{BF}} \)
- 13.8 ppg \( \underline{\text{BF}} \)
- 17.9 ppg \( \underline{\text{BF}} \)
How Buoyancy Affects the Weight of the Drill String

Pipe Wt. \( \#/\text{ft} \) \( \times \left( \frac{65.4 - MW_{\text{ppg}}}{65.4} \right) \times \text{Length}_{\text{Feet}} \)

Example:

Use the following information and the buoyancy factor formula to calculate the immersed weight of these drill strings.

#1
- **Drill Pipe**: 5878’, 21.92#/ft
- **Heavy Weight**: 1300’, 44.6#/ft
- **Drill Collars**: 120’, 108.76#/ft
- **Mud Weight**: 10.2 ppg

Drill String Weight = ____________ lbs

#2
- **Drill Pipe**: 15920’, 26.74#/ft
- **Heavy Weight**: 1300’, 49.0#/ft
- **Drill Collars**: 360’, 97.64#/ft
- **Mud Weight**: 16.1 ppg

Drill String Weight = ____________ lbs
<table>
<thead>
<tr>
<th>Rig Number</th>
<th>Component</th>
<th>Length (ft)</th>
<th>Density (#/ft)</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>Upper Drill Pipe</td>
<td>9800</td>
<td>21.92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Drill Pipe</td>
<td>2816</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy Weight</td>
<td>1708</td>
<td>49.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drill Collars</td>
<td>120</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mud Weight</td>
<td></td>
<td>11.4 ppg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drill String Weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>Upper Drill Pipe</td>
<td>3920</td>
<td>29.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Drill Pipe</td>
<td>11892</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy Weight</td>
<td>1300</td>
<td>57.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Drill Collars</td>
<td></td>
<td>92.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Drill Collars</td>
<td></td>
<td>132.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mud Weight</td>
<td></td>
<td>17.5 ppg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drill String Weight</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How Angle & Buoyancy Affects Drill String Component Weight

Not only does the mud weight affect the weight of the drill string but the hole angle does also. The greater the hole angle, the less effective weight the drill string has. The following formula can be used to determine the weight of pipe immersed in a mud and in a deviated hole.

\[
\text{Pipe Weight} = \text{Pipe Weight} \times BF \times \cos\angle \times \text{Length}
\]

### Example:

<table>
<thead>
<tr>
<th>#1 BHA</th>
<th>360’ Drill Collars</th>
<th>101.25#/ft</th>
<th>__________ #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>810’ Heavy Weight</td>
<td>51#/ft</td>
<td>__________ #</td>
</tr>
<tr>
<td></td>
<td>Mud Weight</td>
<td>13.8 ppg</td>
<td>______ BF</td>
</tr>
<tr>
<td></td>
<td>Hole Angle</td>
<td>38°</td>
<td></td>
</tr>
</tbody>
</table>

BHA Weight = __________ lbs

<table>
<thead>
<tr>
<th>#2 BHA</th>
<th>90’ Drill Collars</th>
<th>98.25#/ft</th>
<th>__________ #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1250’ Heavy Weight</td>
<td>49.7#/ft</td>
<td>__________ #</td>
</tr>
<tr>
<td></td>
<td>Mud Weight</td>
<td>16.0 ppg</td>
<td>______ BF</td>
</tr>
<tr>
<td></td>
<td>Hole Angle</td>
<td>72.4°</td>
<td></td>
</tr>
</tbody>
</table>

BHA Weight = __________ lbs
Estimating Total Drill String Weight In a Deviated Wellbore

As you can see by the lengths given above, part of the drill pipe section would be in the vertical section, part in the build section where angle is being increased, and a third section is in the tangent section where the hole angle is constant. The combination of hole angle and the buoyancy factor will have a direct impact of the actual weight of the string.

- DP: 15252’, 21.92#/ft
- HW: 1029’, 54#/ft
- DC: 270’, 102.78#/ft

KOP: kick-off point
EOB: end of the build

MW: 15.2ppg

KOP @ 9873’
EOB @ 13455’; 62.5° Angle
TD @ 16551’
A practical way of calculating the section of the drill section in the build section is to calculate an average angle for that section. Then apply the cosine of the average angle and the buoyancy factor to arrive at an estimated weight. The following formula can be used to accomplish this.

\[ DP \text{ Weight } 
\frac{\text{# lb/ft}}{\text{BF}} \times \text{COS} \left( \frac{\text{Maximum } \angle}{2} \right) \]

To calculate the weight for the remaining portion of the drill pipe as well as the heavy weight and drill collar sections, use the previously introduced formulas. So, the formulas to be used are as follows:

For the vertical section

\[ \text{Pipe Weight } 
\frac{\text{# lb/ft}}{\text{BF}} \times \text{BF} \times \text{Length}_{\text{Feet}} \]

For the build section

\[ \text{Pipe Weight } 
\frac{\text{# lb/ft}}{\text{BF}} \times \text{BF} \times \text{COS} \left( \frac{\text{Maximum } \angle}{2} \right) \times \text{Length} \]

For the tangent section

\[ \text{Pipe Weight } 
\frac{\text{# lb/ft}}{\text{BF}} \times \text{BF} \times \text{COS} \angle \times \text{Length} \]

Based on this information calculate the weight of the entire drill string from the previous page.

Total drill string weight = ______________ lbs
**Rig Math**

**Tensile Strength**

The tensile strength of drill pipe, heavy weight and collars is based on the cross sectional area and the grade of steel used in making the pipe. We’ll use drill pipe as an example. Drill pipe is manufactured in the following grades:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Minimum Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-75</td>
<td>E – 75,000 psi</td>
</tr>
<tr>
<td>X-95</td>
<td>X – 95,000 psi</td>
</tr>
<tr>
<td>G-105</td>
<td>G – 105,000 psi</td>
</tr>
<tr>
<td>S-135</td>
<td>S – 135,000 psi</td>
</tr>
<tr>
<td>V-155</td>
<td>V – 155,000 psi</td>
</tr>
</tbody>
</table>

The letter designates the alloy the pipe is made of and the number represents the minimum yield in thousands of pounds per square inch of steel.

In order to estimate the tensile strength you must know the pipe grade and the cross sectional area of the steel in square inches. The following formula is used to determine the tensile strength:

\[
\left( OD_{Pipe}^2 - ID_{Pipe}^2 \right) \times 0.7854 \times \text{Minimum Yield}
\]

**Example:**

<table>
<thead>
<tr>
<th>Pipe Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drill Pipe OD</td>
<td>5”</td>
</tr>
<tr>
<td>Drill Pipe ID</td>
<td>4.276”</td>
</tr>
<tr>
<td>Drill Pipe Grade</td>
<td>G (105,000 psi)</td>
</tr>
</tbody>
</table>

\[
\left( 5^2 - 4.276^2 \right) \times 0.7854 \times 105000_{psi} = 553833.8 \approx 553834#
\]
Calculate the tensile strengths for the following grades of drill pipe:

#1 5” OD
4.276” ID
Grade X-95

Tensile = __________ #

#2 4 ½” OD
3.826” ID
Grade S-135

Tensile = __________ #

#3 3 ½” OD
2.763” ID
Grade V-155

Tensile = __________ #
Maximum Overpull

Maximum overpull is the difference between a present string weight and the estimated tensile strength of the top joint of drill pipe. There is usually a safety factor used when the calculation is made, but for this example no safety factor will be used.

Calculate the estimated tensile strength of the drill pipe and then calculate the total weight of the drill string.

**Tensile Strength**

\[
\left( OD_{Pipe}^2 - ID_{Pipe}^2 \right) \times 0.7854 \times \text{Minimum Yield}
\]

**Maximum Overpull**

\[
\text{Tensile Strength} - \left( \text{String Weight} + \text{Drag} \right)
\]

**Example:** a drill string consists of the following components:

- **Drill Pipe:** 11428’ 5” OD, 4.276” ID, Grade G, 23.07#/ft
- **Heavy Weight:** 1320’ 5” OD, 3” ID, 49.7#/ft
- **Drill Collars:** 120’ 7” OD, 3” ID, 106.82#/ft
- **Mud Weight:** 14.3 ppg
- **KOP:** 9860’
- **EOB:** 11428’
- **Hole Angle:** 37 degrees
- **Last Recorded Drag:** 62000#
Rig Math

Drill Pipe Tensile

\[
(OD_{Pipe}^2 - ID_{Pipe}^2) \times 0.7854 \times \text{Minimum Yield}
\]

Buoyancy Factor

\[
\frac{(65.4 - \text{Mud Weight}_{ppg})}{65.4} = \text{Buoyancy Factor}
\]

String Weight

For the vertical section

\[
\text{Pipe Weight}_{#/ft} \times BF \times \text{Length}_{\text{Feet}}
\]

For the build section

\[
\text{Pipe Weight}_{#/ft} \times BF \times \text{COS} \left( \frac{\text{Maximum } \angle}{2} \right) \times \text{Length}
\]

For the tangent section

\[
\text{Pipe Weight}_{#/ft} \times BF \times \text{COS} \angle \times \text{Length}
\]

Maximum Overpull
Drill Pipe Tensile = ____________ #

Buoyancy Factor = ________

String Weight
- Vertical Section = _______________ #
- Build Section = _______________ #
- Tangent Section = _______________ #

Total String Weight = _______________ #

Total Pipe Load = _______________ #

Maximum Overpull = _______________ #
Hydrostatics

Simply defined, hydrostatic pressure is the pressure exerted by a static column of fluid due to two things:

- The density of the fluid
- The vertical length of the column of fluid

We generally think of hydrostatic pressure in terms of a column of mud, but gas, although having slight density, can also exert a hydrostatic pressure.

To estimate the hydrostatic pressure of a column of liquid, the following formula is used:

\[ \text{Hydrostatic Pressure} = 0.052 \times \text{Fluid Weight}_{\text{ppg}} \times \text{Length}_{\text{Vertical}} \]

You’ll notice that the density of the fluid in the formula is in pounds per gallon. Another way of looking at density is in terms of the pressure exerted by a one foot column of that fluid. This is commonly referred to as the fluid gradient. To determine the gradient of a fluid whose density is measured in pounds per gallon perform the following calculation:

\[ \text{Fluid Gradient} = 0.052 \times \text{Fluid Weight}_{\text{ppg}} \]

Some fluids encountered in drilling or completing a well are commonly measured in their gradients such as gas and produced water. If the gradient of a fluid is known simply multiply the gradient times the vertical length of the column to determine the hydrostatic pressure.
## Hydrostatic Pressure Calculations

Calculate the hydrostatic pressure for the following columns of weighted fluids:

<table>
<thead>
<tr>
<th>Mud Weight PPG</th>
<th>Vertical Length ft</th>
<th>Hydrostatic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.4</td>
<td>12398</td>
<td>_______ psi</td>
</tr>
<tr>
<td>17.4</td>
<td>21287</td>
<td>_______ psi</td>
</tr>
<tr>
<td>9.2</td>
<td>8785</td>
<td>_______ psi</td>
</tr>
<tr>
<td>12.4</td>
<td>11280</td>
<td>_______ psi</td>
</tr>
</tbody>
</table>

Calculate the hydrostatic pressure for the following columns of gas and produced water.

<table>
<thead>
<tr>
<th>Gas Gradient</th>
<th>Vertical Length ft</th>
<th>Hydrostatic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>.135 psi/ft</td>
<td>1345</td>
<td>_______ psi</td>
</tr>
<tr>
<td>.1 psi/ft</td>
<td>2000</td>
<td>_______ psi</td>
</tr>
<tr>
<td>.115 psi/ft</td>
<td>1500</td>
<td>_______ psi</td>
</tr>
<tr>
<td>.12 psi/ft</td>
<td>15000</td>
<td>_______ psi</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Water Gradient</th>
<th>Vertical Length ft</th>
<th>Hydrostatic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>.451 psi/ft</td>
<td>7800</td>
<td>_______ psi</td>
</tr>
<tr>
<td>.433 psi/ft</td>
<td>200</td>
<td>_______ psi</td>
</tr>
<tr>
<td>.465 psi/ft</td>
<td>9000</td>
<td>_______ psi</td>
</tr>
<tr>
<td>.487 psi/ft</td>
<td>11000</td>
<td>_______ psi</td>
</tr>
</tbody>
</table>
Hydrostatic Pressure Calculations for Gas and Produced Water

Both gas and produced water are measured in their gradients, or pressure per foot. To calculate the hydrostatic pressure of either, use the following formula.

\[ \text{Gradient}_{\text{PSI}/\text{FT}} \times \text{Vertical Length}_{\text{Feet}} \]

### Hydrostatic Pressure For a Column of Gas

<table>
<thead>
<tr>
<th>#</th>
<th>Gas Gradient</th>
<th>Length</th>
<th>Hydrostatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>.12 psi/ft</td>
<td>687 feet</td>
<td>______ psi</td>
</tr>
<tr>
<td>#2</td>
<td>.134 psi/ft</td>
<td>1129 feet</td>
<td>______ psi</td>
</tr>
<tr>
<td>#3</td>
<td>.1 psi/ft</td>
<td>1267 feet</td>
<td>______ psi</td>
</tr>
</tbody>
</table>

### Hydrostatic Pressure For a Column of Water

<table>
<thead>
<tr>
<th>#</th>
<th>Water Gradient</th>
<th>Length</th>
<th>Hydrostatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>.433 psi/ft</td>
<td>2375 feet</td>
<td>______ psi</td>
</tr>
<tr>
<td>#2</td>
<td>.465 psi/ft</td>
<td>400 feet</td>
<td>______ psi</td>
</tr>
<tr>
<td>#3</td>
<td>.457 psi/ft</td>
<td>4877 feet</td>
<td>______ psi</td>
</tr>
</tbody>
</table>
Based on the information at right, calculate the total hydrostatic pressure in this wellbore.

11200 feet of 16.4 ppg mud

Mud Hydrostatic Pressure = ________ psi

Gas Hydrostatic Pressure = ________ psi

Total Wellbore Hydrostatic Pressure = ________ psi

1287 feet of .134 psi/ft gas
In many cases, wells are drilled overbalanced. The term **overbalanced** means that the hydrostatic pressure of the mud exceeds the pressure within the open hole formations. To obtain an estimate of the overbalance, calculate the difference between the mud hydrostatic pressure and the estimated formation pressure, at a particular depth.

Based on this and the information below, calculate the overbalance for each listed formation pressure at its depth compared to the mud weight.

\[ \text{Formation PSI} = \left(0.052 \times MW \times \text{Length}_{\text{Vertical}} \right) \]

**6860’, Formation Pressure of 3120 psi**

Mud Hydrostatic = ________ psi
Mud Weight of 12.4 ppg
Overbalance = ________ psi

**9261’, Formation Pressure of 4550 psi**

Mud Hydrostatic = ________ psi
Overbalance = ________ psi

**11278’ with a Formation Pressure of 7155 psi**

Mud Hydrostatic = ________ psi
Overbalance = ________ psi
Wellbore Volume Calculations

It’s essential, for many reasons, that the rig crew be able to calculate and keep current with the volume of mud in the hole. The following two formulas are used to acquire and estimate of the hole volume.

To calculate the volume of various components of the drill string, or to calculate the volume of open casing or the open hole, the following is used:

\[
\left( \frac{ID_{Pipe}^2}{1029.4} \right) = \text{Capacity Factor}
\]

\[
\left( \frac{ID_{Pipe}^2}{1029.4} \right) \times \text{Length} = \text{Volume of Interest}
\]

To calculate the volume in a particular annular section the formula below is used.

\[
\left( \frac{ID_{Annulus}^2 - OD_{Pipe}^2}{1029.4} \right) \times \text{Length} = \text{Annulas Volume}
\]
Based on the information given and the two formulas on the preceding page, calculate the wellbore volume.

**Drill String Volume**
- Drill Pipe Volume = ________ bbl
- Heavy Weight Volume = ________ bbl
- Drill Collar Volume = ________ bbl

**Annular Volume**
- DC in Open Hole Volume = ________ bbl
- HW in Open Hole Volume = ________ bbl
- DP in Open Hole Volume = ________ bbl
- DP in Cased Hole Volume = ________ bbl

Casing ID 8.681” shoe set @ 5400’

11000’ of 5” OD x 4.276” ID

8 ½” Open Hole

650’ of 5” OD x 3” ID

360’ of 6 ¾” x 2 ¼”

12010’ TD
Strokes To Displace A Known Volume

In order to determine how many pump strokes it will take to pump a particular volume one must know the volume to be pumped and also the output of the pump. In the case of a triplex pump, the output can be calculated using the following formula:

**Triplex Pump Output Formula**

\[
ID_{\text{Liner}}^2 \times Stroke \text{ Length}_{\text{Inches}} \times 0.000243 \times \text{Volumetric Efficiency}
\]

It’s fairly easy to find out the liner size and stroke length, but the volumetric efficiency can and should be determined with a simple field test.

First, calculate the pump output as though the pump operates at 100% efficiency. This is done by using the above formula and omitting the volumetric efficiency. For this example we’ll use:

- Liner Size: 6 3⁄4”
- Stroke Length: 12 inches

\[
ID_{\text{Liner}}^2 \times Stroke \text{ Length}_{\text{Inches}} \times 0.000243 = \text{BBL / STK}
\]

\[
6.75^2_{\text{Liner}} \times 12_{\text{Inches}} \times 0.000243 = 0.1329 \text{ BBL / STK}
\]
Next, calculate the strokes required to pump a known volume. This is done by using this formula:

\[
\frac{\text{Volume}_{\text{BBL}}}{\text{Pump Output}_{\text{BBL} / \text{STKS}}} = \text{Strokes}
\]

Continuing with this example, we’ll use a volume of 10 bbl. The pump should be lined up to a calibrated tank such as a trip tank so that the pumped volume can be accurately measured. The number of strokes required to pump 10 bbl is calculated:

\[
\frac{10_{\text{BBL}}}{.1329_{\text{BBL} / \text{STKS}}} = 75.2 \approx 75_{\text{Strokes}}
\]

In this case, the driller lined up the pump to a trip tank and pumped 10 bbl. He noticed that it took 79 strokes to pump 10 bbl. Obviously the pump is not 100% efficient. The efficiency can then be determined by calculating a ratio between the calculated strokes and the observed strokes.

\[
\frac{75 \text{ calculated strokes}}{81 \text{ observed strokes}} = .9259
\]

.9259 is the same as 92.59% efficient. The decimal figure of .9259 is used in determining the pump output.
So the actual pump output is calculated using the following:

\[ ID_{\text{Liner}}^2 \times \text{Stroke Length}_{\text{Inches}} \times 0.000243 \times \text{Volumetric Efficiency} \]

\[ 6.75^2_{\text{Liner}} \times 12_{\text{Inches}} \times 0.000243 \times 0.9259 = .1230_{\text{BBL/STK}} \]

Once the actual pump output is known, the displacement strokes can be calculated and if the pump rate is known, then the time required to displace that volume can also be calculated.

For example, the wellbore volume has been calculated to be 1200 bbl and it is to be totally displaced at a rate of 75 spm. Using this information and the calculated pump output above, we can perform both calculations.

\[ \frac{1200_{\text{BBL}}}{.1230_{\text{BBL/STK}}} = 9756_{\text{Strokes}} \]

To determine the approximate circulating time to displace this volume:

\[ \frac{9756_{\text{Strokes}}}{75_{\text{SPM}}} = 130_{\text{min}} \]
Calculate this wellbore volume and determine the total pump strokes required to pump the entire volume along with the approximate time to get this done.

Casing ID 8.755” shoe set @ 7256’

13542’ 5” OD x 4.276” ID

8 ½” Open Hole

810’ 5” OD x 3” ID

180’ of 7” x 3”

14532’ TD

Pump: 5 ¾” Liner, 10” stroke
92% Efficiency

Pump Rate 80 spm

Use the following page to record your calculations.
Drill Pipe Volume =

Heavy Weight Volume =

Drill Collar Volume =

Drill String Volume =

Drill Collars in Open Hole Volume =

Heavy Weight in Open Hole Volume =

Drill Pipe in Open Hole Volume =

Drill Pipe in Cased Hole Volume =

Annular Volume =

Pump Output =

Strokes to Displace Drill String =

Approximate Circulating Time =
Determining Required SPM For A Desired BPM Flowrate

Based on the pump output and a desired flowrate in BPM you can calculate the required SPM rate to run the pump. The formula below will accomplish this.

\[
\frac{\text{Desired Flowrate}_{\text{BPM}}}{\text{Pump Output}_{\text{BBL/STK}}}
\]

**Example:** We want to pump at a flowrate of 3½ BPM using a triplex pump having a liner of 6½”, a stroke length of 10”, and an efficiency of 90%.

First, calculate the pump output.

\[
6.5^2_{\text{Liner}} \times 10_{\text{Inches}} \times .000243 \times .90 = .0924_{\text{BBL/STK}}
\]

Calculate the required SPM that will result in a flowrate of 3½ BPM.

\[
\frac{3.5_{\text{BPM}}}{.0924_{\text{BBL/STK}}} = 37.8 \approx 38_{\text{SPM}}
\]
From the information provided below, calculate the required SPM rates to run the pump to achieve the desired flowrates in BPM.

#1  
Pump:  8” liner, 12” stroke, 88% efficiency  
Desired Flowrate:  4 bpm  
Required Pump Rate = _________ spm

#2  
Pump:  6” liner, 10” stroke, 92% efficiency  
Desired Flowrate:  5 bpm  
Required Pump Rate:  _________ spm

#3  
Pump:  3 ½” liner, 8” stroke, 80% efficiency  
Desired Flowrate:  2 ¼ BPM  
Required Pump Rate:  _________ spm

#4  
Pump:  4 ¾” liner, 6 ½” stroke, 88% efficiency  
Desired Flowrate:  3 bpm  
Required Pump Rate:  _________ spm
Determining The Flowrate Based On Pump Rate in SPM

If you need to know the flowrate in BPM when pumping at a certain SPM rate, this formula below can be used.

\[ \text{Pump Output} \times \text{SPM} \]

Determine the pump output using the formula previously presented, then multiply the pump rate in SPM by the pump output.

**Example:** A triplex pump having a liner of 8”, a stroke length of 12”, and an efficiency of 92% is being run at a rate of 52 spm. What is the flowrate in BPM?

Calculate the pump output

\[ 8^2 \times 12 \times 0.000243 \times 0.92 = 0.1717 \]

Calculate the flowrate in BPM

\[ 0.1717 \times 52 = 8.9 \text{ BPM} \]
Use the information below to determine the flowrates in BPM based on the pump outputs and the pump rates in SPM.

<table>
<thead>
<tr>
<th>#</th>
<th>Pump:</th>
<th>Pump Rate spm:</th>
<th>Flowrate = __________ bpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8” liner, 12” stroke, 88% efficiency</td>
<td>32 spm</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6” liner, 10” stroke, 92% efficiency</td>
<td>40 spm</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3 ½” liner, 8” stroke, 80% efficiency</td>
<td>70 spm</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4 ¾” liner, 6 ½” stroke, 88% efficiency</td>
<td>65 spm</td>
<td></td>
</tr>
</tbody>
</table>
Estimating Mud Tank Volume

To determine the volume of a rectangular steel pit, the dimensions of the pit must be known. Namely the **height**, **length** and **width**.

Once these dimensions are known the following formula can be used to calculate the volume of the pit in bbl.

\[
\text{Volume} = \text{Height}_{\text{feet}} \times \text{Length}_{\text{feet}} \times \text{Width}_{\text{feet}} \times 1781 \text{ Barrels}
\]

Let’s suppose this pit measures: 6 feet in height, 8 feet in width, and 15 feet in length. The volume can be calculated as such:

\[
6_{\text{feet}} \times 15_{\text{feet}} \times 8_{\text{feet}} \times 1781 = 128_{\text{bbl}}
\]
Calculate the volume of these tanks:

#1  
Height 8.5 feet  
Length 24 feet  
Width 10 feet  
Volume = ________ bbls  

#2  
Height 12 feet  
Length 30 feet  
Width 12 feet  
Volume = ________ bbls  

#3  
Height 7 feet  
Length 12 feet  
Width 5 feet  
Volume = ________ bbls
It may be beneficial to know how many BBLS occupy each inch of height in a tank, or how many inches equate to a certain number of BBLS. This can be accomplished using the following:

**Tank Volume BBL/Inch:**

\[
\frac{\text{Tank Volume}_{BBL}}{(\text{Height}_{Feet} \times 12)}
\]

**Tank Volume Inches/BBL:**

\[
\frac{(\text{Height}_{Feet} \times 12)}{\text{Tank Volume}_{BBL}}
\]

Calculate the volume of this tank and determine its measurement in BBL/Inch and Inches/BBL.

BBL/Inch = ________

Inches/BBL = ________
The volume of a vertically-oriented cylindrical tank, commonly called a frac tank, can be calculated by using the following formula.

\[
\left(\frac{\text{Diameter}_{\text{Feet}} \times 12}{1029.4}\right)^2 \times \text{Height}_{\text{Feet}}
\]

\[
\left(\frac{8_{\text{Feet}} \times 12}{1029.4}\right)^2 \times 20_{\text{Feet}} = 179_{\text{BBL}}
\]

Calculate the volume of these tanks:

<table>
<thead>
<tr>
<th></th>
<th>Height</th>
<th>Diameter</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>16 feet</td>
<td>6.5 feet</td>
<td>______ BBL</td>
</tr>
<tr>
<td>#2</td>
<td>8 feet</td>
<td>4 feet</td>
<td>______ BBL</td>
</tr>
</tbody>
</table>
Similarly to the rectangular tank, the volume in BBL/Inch and Inches/BBL can also be calculated for a cylindrical tank.

\[
\frac{\text{Tank Volume}_{BBL}}{(\text{Height}_{Feet} \times 12)}
\]

\[
\frac{(\text{Height}_{Feet} \times 12)}{\text{Tank Volume}_{BBL}}
\]

Calculate the volume of this tank and determine its measurement in BBL/Inch and Inches/BBL.

BBL/Inch = ________

Inches/BBL = ________