OPERATOR MATH REVIEW

1st Edition

PROFESSIONAL DEVELOPMENT COURSE

HOW TO CALCULATE CHLORINE DOSAGE TO DISINFECT A WELL USING CALCIUM HYPOCHLORITE

EQUIPMENT

- 20 litre bucket
- HSCH Chlorine granules or powder

METHOD

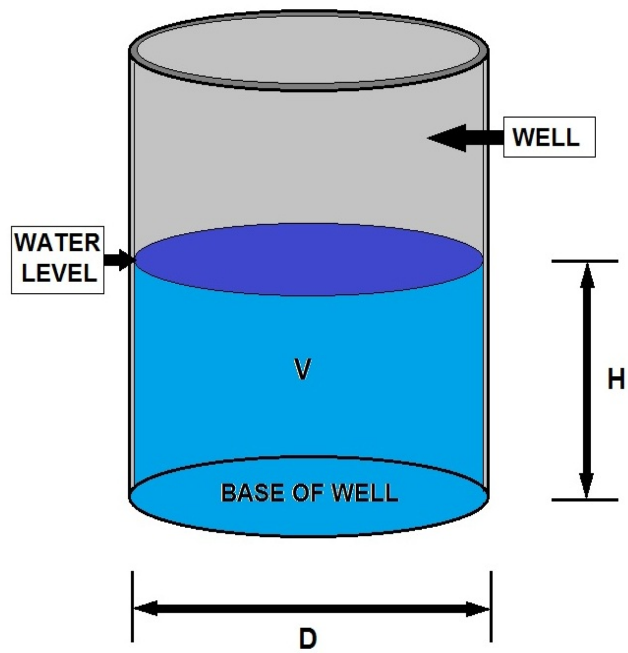
- Calculate the volume of water in the well using formula:

$$V = \frac{\pi D^2 h}{4}$$

WHERE

V = Volume of water
D = Diameter
h = Depth of water
π = 3.142

- Fill bucket with clear water from source
- Add about 300g of HSCH and stir (dissolve)
- For every cubic meter of water, add 10 litres (half bucket) of chlorine solution.
- Double the quantity of HSCH added if the solution is to be used for cleaning well lining or aprons



Technical Learning College

Printing and Saving Instructions

The best thing to do is to download this pdf document to your computer desktop and open it with Adobe Acrobat DC reader.

Adobe Acrobat DC reader is a free computer software program and you can find it at Adobe Acrobat's website.

You can complete the course by viewing the course materials on your computer or you can print it out. Once you've paid for the course, we'll give you permission to print this document.

Printing Instructions: If you are going to print this document, this document is designed to be printed double-sided or duplexed but can be single-sided.

This course booklet does not have the assignment. Please visit our website and download the assignment also.

Internet Link to Assignment…
http://www.abctlc.com/PDF/OperatorMathAss.pdf

State Approval Listing Link, check to see if your State accepts or has pre-approved this course. Not all States are listed. Not all courses are listed. Do not solely trust our list for it may be outdated. It is your sole responsibility to ensure this course is accepted for credit. No refunds.

Professional Engineers; Most states will accept our courses for credit but we do not officially list the States or Agencies acceptance or approvals.

State Approval Listing URL…
http://www.tlch2o.com/PDF/CEU%20State%20Approvals.pdf

You can obtain a printed version from TLC for an additional $59.95 plus shipping charges.

All downloads are electronically tracked and monitored for security purposes.

Contributing Editors

Joseph Camerata has a BS in Management with honors (magna cum laude). He retired as a Chemist in 2006 having worked in the field of chemical, environmental, and industrial hygiene sampling and analysis for 40 years. He has been a professional presenter at an EPA analytical conference at the Biosphere in Arizona and a presenter at an AWWA conference in Mesa, Arizona. He also taught safety classes at the Honeywell and City of Phoenix, and is a motivational/inspirational speaker nationally and internationally.

Dr. Eric Pearce S.M.E., chemistry and biological review.

Dr. Pete Greer, S.M.E., retired biology instructor.

Jack White, S.M.E., Environmental, Health, Safety expert. Art Credits.

Copyright Notice

Some States and many employers require the final exam to be proctored.

Do not solely depend on TLC's Approval list for it may be outdated.

A second certificate of completion for a second State Agency $50 processing fee.

Most of our students prefer to do the assignment in Word and e-mail or fax the assignment back to us. We also teach this course in a conventional hands-on class. Call us and schedule a class today.

Technical Learning College's Scope and Function

Welcome to the Program,

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds several different governmental agency approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print- based format and you are welcome to examine this material on your computer with no obligation. We will beat any other training competitor's price for the same CEU material or classroom training.

Our courses are designed to be flexible and for you do finish the material on your leisure. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and assignments. All of TLC's CEU courses allow students to submit assignments using e-mail or fax, or by postal mail. (See the course description for more information.)

Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored closed-book exams depending upon your state or employer requirements.

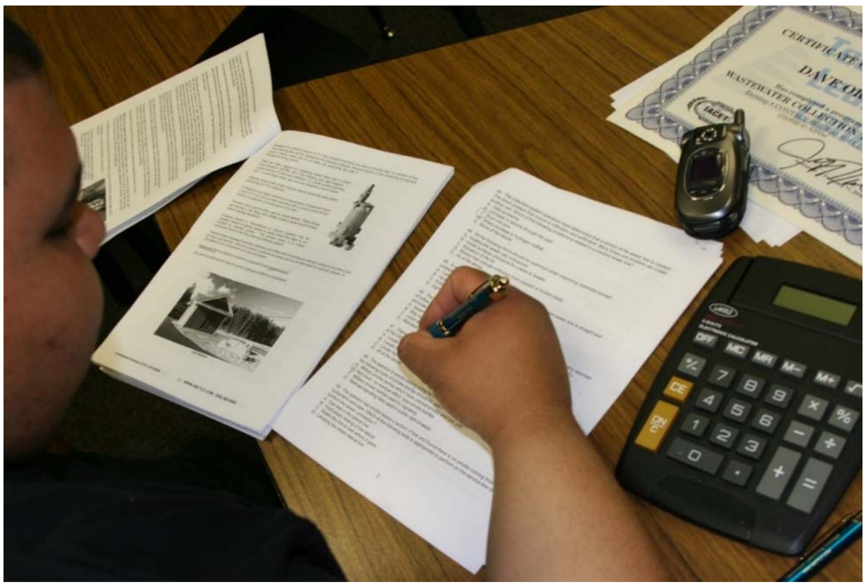
Flexible Learning
At TLC, there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You will work at your own pace, completing assignments in time frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

Course Structure
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student friendly course design allows you the most flexibility in choosing when and where you will study.

Classroom of One
TLC offers you the best of both worlds. You learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members are assigned at the beginning of each course providing the academic support you need to successfully complete each course.

No Data Mining Policy
Unlike most online training providers, we do not use passwords or will upload intrusive data mining software onto your computer. We do not use any type of artificial intelligence in our program. Nor will we sell you any other product or sell your data to others as with many of our competitors. Unlike our training competitors, we have a telephone and we humanly answer.

Satisfaction Guaranteed
We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 20,000 students.



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail. If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of $50.

Contact Numbers

Fax (928) 468-0675
Email Info@tlch2o.com
Telephone (866) 557-1746

TLC's CEU Course Description

OPERATOR MATH REVIEW CEU TRAINING COURSE

This course is a review of basic operator certification mathematics. Topics include simplifying expressions, evaluating and solving equations. Real world applications are presented within the course content and a function's approach is emphasized. This review course is designed to give students the requisite skills that provide a foundation for all future mathematics. Throughout the course, mathematical concepts will be taught with an emphasis on real-world operator applications, treatment technologies, and cross-curricular interaction.

Another goal of this course is to prepare the operator for advanced math problems commonly encountered in the certification examination. Many of these problems involve multiple steps and the manipulation of formulas.

You will not need any other materials for this course.

Target Audience
The primary target audience for this course are certified water/wastewater operators including water distribution workers, well drillers, pump installers, water treatment operators, and wastewater treatment operators. Also included are people interested in working in a water treatment/wastewater treatment or distribution facility and/or wishing to maintain CEUs for a certification license or to learn how to perform operator math calculations. There are no prerequisites, and no other materials are needed for this course.

Course Statement of Need
The understanding of the mathematics of water calculations including hydraulics (flows, pressures, volumes, horsepower, velocities) and water/wastewater treatment (chlorination, detention time, chemical dosage) is an important tool for all water/wastewater system operators and is commonly used daily.

Prerequisite
Basic math knowledge on a high school level is recommended for successful completion of this course.

Final Examination for Credit
Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Course Procedures for Registration and Support
All of Technical Learning College's distance learning courses have complete registration and support services offered. Delivery of services will include e-mail, web site, telephone, fax and mail support. TLC will attempt immediate and prompt service.

When a student registers for a correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work. If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request. All students will be tracked by a unique computer generated number assigned to the student.

Disclaimer and Security Notice
The student shall understand that it their responsibility to ensure that this CEU course is either approved or accepted in my State for CEU credit. The student shall understand and follow State laws and rules concerning distance learning courses and understand these rules change on a frequent basis and will not hold Technical Learning College responsible for any changes. The student shall understand that this type of study program deals with dangerous conditions and will not hold Technical Learning College, Technical Learning Consultants, Inc. (TLC) liable for any errors or omissions or advice contained in this CEU education training course or for any violation or injury caused by this CEU education training course material. The student shall contact TLC if they need help or assistance and double-check to ensure my registration page and assignment has been received and graded.

Student Verification
The student shall submit a driver's license for signature verification and track their time worked on the assignment. The student shall sign an affidavit verifying they have not cheated and worked alone on the assignment. All student attendance is tracked on the student attendance database.

Feedback Mechanism (examination procedures)
Each student will receive a feedback or survey form as part of his or her study packet. You will be able to find this form in the front of the assignment lesson. The student can e-mail, snail mail or telephone TLC for any concern at any time. Most of these concerns will be answered in 2 hours but not more than 24 hours. TLC has three support staff administrators with modern computers and all have excellent communication and computer skills able to respond and track all students and required forms and assignment. We have a dedicated computer student tracking system database that is backed-up on a daily based and this information is secured and stored at a secure offsite location.

TLC Contact Information
All instructors and administrative staff are obligated to respond within 1 day by email, snail mail or telephone providing proper guidance to successfully complete the assignment. Email and telephone inquiries are handled quickly, generally within 2 hours of the call.

We encourage students to complete their work with less frustration and fewer delays by calling or e-mailing us for any concern. We attempt to provide direct interaction similar to conventional classroom training.

Security and Integrity
All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified. A random test generator will be implemented to protect the integrity of the assignment.

Student Information Personal Data Security Procedures
All information regarding the student is strict and privileged only. This information is held in secure databases and is not sold or provided to any one unless the student requests a copy or a State agency does an audit. Even during audits, we restrict confidential information unless the Agency can provide a legitimate excuse. Some of this security information and data is priority and details are not provided. Students are not provided with any passwords at this time.

Grading Criteria / Certificate of Completion
TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, the student will only receive a pass/fail notice. In order to pass your final assignment, you are required to obtain a minimum score of 70% on your assignment. The certificate of completion will have all text in capital letters and there is a water mark of the Technical Learning College in three colors along with anti-counterfeiting security measures on the edge of the certificate. An electronic copy is assigned to the student's electronic record with issue date.

Failure
If the student fails the examination, they are provided with two more chances to successfully pass the exam with a score of 70% or better. The student may receive a different and randomly generated exam. Upon failure of an exam, the student can submit their concerns in writing or submit a survey form and has the option to receive instructor assistance that would be equivalent to conventional classroom assistance in discovering the areas that are deficient. The instructor has the option in describing the assistance method or procedure depending upon the student's deficiencies.

Forfeiture of Certificate (Cheating)
If a student is found to have cheated on an examination, the penalty may include--but is not limited to--expulsion; foreclosure from future classes for a specified period; forfeiture of certificate for course/courses enrolled in at TLC; or all of the above in accordance with TLC's Student Manual. A letter notifying the student's sponsoring organization (State Agency) of the individual's misconduct will be sent by the appropriate official at TLC. No refund will be given for paid courses. An investigation of all other students that have taken the same assignment within 60 day period of the discovery will be re-examined for fraud or cheating. TLC reserves the right to revoke any published certificates and/or grades if cheating has been discovered for any reason and at any time. Students shall sign affidavit agreeing with all security measures. The student shall submit a driver's license for signature verification and track their time worked on the assignment. The student shall sign an affidavit verifying they have not cheated and worked alone on the assignment.

Student Assistance
The student shall contact TLC if they need help or assistance and double-check to ensure my registration page and assignment has been received and graded.

Instructions for Written Assignments
The Operator Math Review training CEU course uses multiple choice questions. Answers may be written in this manual or typed out on a separate answer sheet. TLC prefers that students type out and e-mail their answer sheets to info@tlch2o.com, but they may be faxed to (928) 468-0675.

Final Examination for Credit
Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Required Texts
This course comes complete and does not require any other materials.

Feedback Mechanism (Examination Procedures)
A feedback form is included in the front of the study assignment packet.

Environmental Terms, Abbreviations, and Acronyms
TLC provides a glossary in the rear of this manual that defines, in non-technical language, commonly used environmental terms appearing in publications and materials, as well as abbreviations and acronyms used throughout the EPA and other governmental agencies.

Record Keeping and Reporting Practices
TLC keeps all student records for a minimum of five years. It is the student's responsibility to give the completion certificate to the appropriate agencies.

ADA Compliance
TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs. Course content may vary from this outline to meet the needs of these particular students.

Note to Students
Keep a copy of everything that you submit! If your work is lost, you can submit your copy for grading. If you do not receive your certificate of completion or other results within two to three weeks after submitting it, please contact your instructor.

Educational Mission
The educational mission of TLC is:
To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,

To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,

To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,

To provide a forum in which students can exchange experiences and ideas related to environmental education,

To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.

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Math Tables and Conversions

General Math Concepts

Operator Math Practice Section

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Key Math Terms

Area: Area is the number of square units that covers a shape or figure.

Decimal Point: A Decimal point is used to represent numbers that are not whole numbers. It is used to indicate the portion of something which does not make up a whole unit.

Denominator: The denominator is the expression written below the line in a fraction. It indicates the number of parts into which one whole is divided.

Density: Density is how much a certain volume of something weighs. Density of a liquid is calculated by dividing the weight of the liquid by its volume. In the metric system, the density of water is always 1.

Diameter: The diameter is the longest distance from one end of a circle to the other.

Fraction: A fraction is an expression that indicates the quotient of two quantities, such as 1/3.

Integer: An integer is the whole portion of a number. It does not include any part of the decimal, which could be part of the number. For example, if a number is 25.33, the integer is 25.

Numerator: The numerator is the expression written above the line in a fraction. It indicates the number of parts of the whole.

Radius: The radius is the distance from the center of a circle to any point on the circle. It is equal to one-half of the diameter.

Rounding: Rounding is a technique used in conjunction with significant figures to properly reflect the accuracy of a measurement. When rounding, you adjust a value to properly reflect its intended usage.

Specific gravity: Specific gravity is a term used in chemical feed that refers to the density of a substance compared to the density of water. In the metric system, specific gravity is equal to density. In the English system it is calculated by dividing the density of a substance by the density of water.

Volume: Volume is a measurement of space or capacity.

Common Math Conversion Factors

1 PSI = 2.31 Feet of Water
1 Foot of Water = .433 PSI
1.13 Feet of Water = 1 Inch of Mercury
454 Grams = 1 Pound
2.54 CM =Inch
1 Gallon of Water = 8.34 Pounds
1 mg/L = 1 PPM
17.1 mg/L = 1 Grain/Gallon
1% = 10,000 mg/L
694 Gallons per Minute = MGD
1.55 Cubic Feet per Second = 1 MGD
60 Seconds = 1 Minute
1440 Minutes = 1 Day
.746 kW = 1 Horsepower

LENGTH
12 Inches = 1 Foot
3 Feet = 1 Yard
5,280 Feet = 1 Mile

AREA
144 Square Inches = 1 Square Foot
43,560 Square Feet = 1 Acre

VOLUME
1000 Milliliters = 1 Liter
3.785 Liters = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Dimensions

SQUARE: Area (sq.ft.) = Length X Width
Volume (cu.ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft.) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. Ft.) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter ^{2} X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14)\ (\text{Diameter})^3}{(6)}$

Circumference = 3.14 X Diameter

General Conversions
Flowrate

Multiply	**—>**	**to get**
to get	**<—**	**Divide**
cc/min	1	mL/min
cfm (ft^3/min)	28.31	L/min
cfm (ft^3/min)	1.699	m^3/hr
cfh (ft^3/hr)	472	mL/min
cfh (ft^3/hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m^3/hr
GPM	3.785	L/min
oz/min	29.57	mL/min

POUNDS PER DAY= Flow (MG) X Concentration (mg/L) X 8.34
***AKA* Solids Applied Formula** = Flow X Dose X 8.34

PERCENT EFFICIENCY = $\frac{\text{In – Out}}{\text{In}}$ X 100

TEMPERATURE: ^{0}F = (^{0}C X 9/5) + 32 9/5 =1.8
^{0}C = (^{0}F - 32) X 5/9 5/9 = .555

CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)

FLOW RATE (Q): Q = A X V (**Q**uantity = **A**rea X **V**elocity)

FLOW RATE (gpm): Flow Rate (gpm) = $\frac{2.83\ (\text{Diameter, in})^2\ (\text{Distance, in})}{\text{Height, in}}$

% SLOPE = $\frac{\text{Rise (feet)}}{\text{Run (feet)}}$ X 100

ACTUAL LEAKAGE = $\frac{\text{Leak Rate (GPD)}}{\text{Length (mi.) X Diameter (in)}}$

VELOCITY = $\frac{\text{Distance (ft)}}{\text{Time (Sec)}}$

HYDRAULIC RADIUS (ft) = $\frac{\text{Cross Sectional Area of Flow (ft)}}{\text{Wetted pipe Perimeter (ft)}}$

WATER HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{3960}$

BRAKE HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{\text{3960 X Pump Efficiency}}$

MOTOR HORSEPOWER = $\frac{\text{Flow (gpm) X Head (ft)}}{\text{3960 X Pump Eff. X Motor Eff.}}$

MEAN OR AVERAGE = $\frac{\text{Sum of the Values}}{\text{Number of Values}}$

TOTAL HEAD (ft) = Suction Lift (ft) X Discharge Head (ft)

SURFACE LOADING RATE (gal/min/sq.ft) = $\frac{\text{Flow Rate (gpm)}}{\text{Surface Area (sq. ft)}}$

MIXTURE STRENGTH (%) = $\frac{\text{(Volume 1, gal) (Strength 1, \%) + (Volume 2, gal) (Strength 2,\%)}}{\text{(Volume 1, gal) + (Volume 2, gal)}}$

INJURY FREQUENCY RATE = $\frac{\text{(Number of Injuries) 1,000,000}}{\text{Number of hours worked per year}}$

DETENTION TIME (hrs.) = $\frac{\text{Volume of Basin (gals)} \times 24 \text{ hrs.}}{\text{Flow (GPD)}}$

SLOPE = $\frac{\text{Rise (ft)}}{\text{Run (ft)}}$

SLOPE (%) = $\frac{\text{Rise (ft)} \times 100}{\text{Run (ft)}}$

POPULATION EQUIVALENT (PE):

1 PE = .17 Pounds of BOD per Day
1 PE = .20 Pounds of Solids per Day
1 PE = 100 Gallons per Day

LEAKAGE (GPD/inch) = $\frac{\text{Leakage of Water per Day (GPD)}}{\text{Sewer Diameter (inch)}}$

CHLORINE DEMAND (mg/L) = Chlorine Dose (mg/L) – Chlorine Residual (mg/L)

MANNING'S EQUATION

τQ = Allowable time for decrease in pressure from 3.5 PSI to 2.5 PSI
τq = As below

$\tau Q = (0.022)\,(d_1{}^2 L_1)/Q$

$\tau q = \frac{[\,0.085]}{q}\;[(d_1{}^2 L1)/(d_1 L_1)]$

Q = 2.0 cfm air loss
θ = .0030 cfm air loss per square foot of internal pipe surface
δ = Pipe diameter (inches)
L = Pipe Length (feet)

$V = \frac{1.486}{\nu} R^{2/3} S^{1/2}$

V = Velocity (ft./sec.)
ν = Pipe Roughness
R = Hydraulic Radius (ft)
S= Slope (ft/ft)

HYDRAULIC RADIUS (ft) = $\frac{\text{Flow Area (ft. 2)}}{\text{Wetted Perimeter (ft.)}}$

WIDTH OF TRENCH (ft) = Base (ft) + (2 Sides) X $\frac{\text{Depth (ft 2)}}{\text{Slope}}$

Common Water Formulas/Conversion Table

Acid Feed Rate = $\frac{\text{(Waste Flow) (Waste Normality)}}{\text{Acid Normality}}$

Alkalinity = $\frac{\text{(mL of Titrant) (Acid Normality) (50,000)}}{\text{mL of Sample}}$

Amperage = Voltage ÷ Ohms

Area of Circle = (0.785)(Diameter^2) OR (π)(Radius^2)

Area of Rectangle = (Length)(Width)

Area of Triangle = $\frac{\text{(Base) (Height)}}{2}$

C Factor Slope = Energy loss, ft. ÷ Distance, ft.

C Factor Calculation = Flow, GPM ÷ [193.75 (Diameter, ft.)$^{2.63}$(Slope)$^{0.54}$]

Chemical Feed Pump Setting, % Stroke = $\frac{\text{(Desired Flow) (100\%)}}{\text{Maximum Flow}}$

Chemical Feed Pump Setting, mL/min =

$$\frac{\text{(Flow, MGD) Dose, mg/L) (3.785L/gal) (1,000,000 gal/MG)}}{\text{(Liquid, mg/mL) (24 hr / day) (60 min/hr)}}$$

Chlorine Demand (mg/L) = Chlorine dose (mg/L) – Chlorine residual (mg/L)

Circumference of Circle = (3.141)(Diameter)

Composite Sample Single Portion = $\frac{\text{(Instantaneous Flow) (Total Sample Volume)}}{\text{(Number of Portions) (Average Flow)}}$

Detention Time = $\frac{\text{Volume}}{\text{Flow}}$

Digested Sludge Remaining, % = $\frac{\text{(Raw Dry Solids) (Ash Solids) (100\%)}}{\text{(Digested Dry Solids) (Digested Ash Solids)}}$

Discharge = $\frac{\text{Volume}}{\text{Time}}$

Dosage, lbs/day = (mg/L)(8.34)(MGD)

Dry Polymer (lbs.) = (gal. of solution)(8.34 lbs/gal)(% polymer solution)

Efficiency, % = $\frac{\text{(In – Out) (100\%)}}{\text{In}}$

Feed rate, lbs/day = $\frac{\text{(Dosage, mg/L) (Capacity, MGD) (8.34 lbs/gals)}}{\text{(Available fluoride ion) (Purity)}}$

Feed rate, gal/min (Saturator) = $\frac{\text{(Plant capacity, gal/min.) (Dosage, mg /L)}}{\text{18,000 mg/L}}$

Filter Backwash Rate = $\frac{\text{Flow}}{\text{Filter Area}}$

Filter Yield, lbs/hr/sq. ft = $\frac{\text{(Solids Loading, lbs/day) (Recovery, \% / 100\%)}}{\text{(Filter operation, hr/day) (Area, ft}^2\text{)}}$

Flow, cu. ft./sec. = (Area, Sq. Ft.)(Velocity, ft./sec.)

Gallons/Capita/Day = $\frac{\text{Gallons / day}}{\text{Population}}$

Hardness = $\frac{\text{(mL of Titrant) (1,000)}}{\text{mL of Sample}}$

Horsepower (brake) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3,960) (Efficiency)}}$

Horsepower (motor) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3960) (Pump, Eff) (Motor, Eff)}}$

Horsepower (water) = $\frac{\text{(Flow, gpm) (Head, ft)}}{\text{(3960)}}$

Hydraulic Loading Rate = $\frac{\text{Flow}}{\text{Area}}$

Leakage (actual) = Leak rate (GPD) ÷ [Length (mi.) x Diameter (in.)]

Mean = Sum of values ÷ total number of values

Mean Cell Residence Time (MCRT) = $\frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs / day + SS lost, lbs / day}}$

Organic Loading Rate = $\frac{\text{Organic Load, lbs BOD / day}}{\text{Volume}}$

Oxygen Uptake = $\frac{\text{Oxygen Usage}}{\text{Time}}$

Pounds per day = (Flow, MGD) (Dose, mg/L) (8.34)

Population Equivalent = $\frac{\text{(Flow MGD) (BOD, mg/L) (8.34 lbs / gal)}}{\text{Lbs BOD / day / person}}$

RAS Suspended Solids, mg/l = $\frac{1,000,000}{SVI}$

RAS Flow, MGD = $\frac{\text{(Infl. Flow, MGD) (MLSS, mg/l)}}{\text{RAS Susp. Sol., mg/l – MLSS, mg/l}}$

RAS Flow % = $\frac{\text{(RAS Flow, MGD) (100 \%)}}{\text{Infl. Flow, MGD}}$

Reduction in Flow, % = $\frac{\text{(Original Flow – Reduced Flow) (100\%)}}{\text{Original Flow}}$

Slope = $\frac{\text{Drop or Rise}}{\text{Run or Distance}}$

Sludge Age = $\frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs / day}}$

Sludge Index = $\frac{\text{\% Settleable Solids}}{\text{\% Suspended Solids}}$

Sludge Volume Index = $\frac{\text{(Settleable Solids, \%) (10,000)}}{\text{MLSS, mg/L}}$

Solids, mg/L = $\frac{\text{(Dry Solids, grams) (1,000,000)}}{\text{mL of Sample}}$

Solids Applied, lbs/day = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

Solids Concentration = $\frac{\text{Weight}}{\text{Volume}}$

Solids Loading, lbs/day/sq ft = $\frac{\text{Solids Applied, lbs / day}}{\text{Surface Area, sq ft}}$

Surface Loading Rate = $\frac{\text{Flow}}{\text{Rate}}$

Total suspended solids (TSS), mg/L =
(Dry weight, mg)(1,000 mL/L) ÷ (Sample vol., mL)

Velocity = $\frac{\text{Flow}}{\text{Area}}$ **O R** $\frac{\text{Distance}}{\text{Time}}$

Volatile Solids, % = $\frac{\text{(Dry Solids - Ash Solids) (100\%)}}{\text{Dry Solids}}$

Volume of Cone = (1/3)(0.785)(Diameter^2)(Height)

Volume of Cylinder = (0.785)(Diameter^2)(Height) OR (π)(r^2)(h)

Volume of Rectangle = (Length)(Width)(Height)

Volume of Sphere = [(π)(diameter^3)] ÷ 6

Waste Milliequivalent = (mL) (Normality)

Waste Normality = $\frac{\text{(Titrant Volume) (Titrant Normality)}}{\text{Sample Volume}}$

Weir Overflow Rate = $\frac{\text{Flow}}{\text{Weir Length}}$

Other Conversion Factors

1 acre = 43,560 square feet
1 cubic foot = 7.48 gallons
1 foot = 0.305 meters
1 gallon = 3.785 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694.45 gallons per minute
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet of water
1% = 10,000 mg/L
Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)
Degrees Fahrenheit = (Degrees Celsius * 9/5) + 32
64.7 grains = 1 cubic foot
1,000 meters = 1 kilometer
1,000 grams = 1 kilogram
1,000 milliliters = 1 liter
144 square inches = 1 square foot
1.55 cubic feet per second = 1 MGD
1 meter = 3.28 feet
π = 3.141

Metric System

Prefixes and Symbols Prefix	Symbol	Meaning
Micro-	μ	0.000 001
Milli-	M	0.001
Centi-	C	0.01
Deci-	D	0.1
Unit		1
Deka-	Da	10
Hecto-	H	100
Kilo-	K	1,000
Mega-	M	1,000,000

Metric System

Length

1 centimeter (cm)	=	10 millimeters (mm)
1 inch	=	2.54 centimeters (cm)
1 foot	=	0.3048 meters (m)
1 foot	=	12 inches
1 yard	=	3 feet
1 meter (m)	=	100 centimeters (cm)
1 meter (m)	≅	3.280839895 feet
1 furlong	=	660 feet
1 kilometer (km)	=	1000 meters (m)
1 kilometer (km)	≅	0.62137119 miles
1 mile	=	5280 ft
1 mile	=	1.609344 kilometers (km)
1 nautical mile	=	1.852 kilometers (km)

Area

1 square foot	=	144 square inches
1 square foot	=	929.0304 square centimeters
1 square yard	=	9 square feet
1 square meter	≅	10.7639104 square feet
1 acre	=	43,560 square feet
1 hectare	=	10,000 square meters
1 hectare	≅	2.4710538 acres
1 square kilometer	=	100 hectares
1 square mile	≅	2.58998811 square kilometers
1 square mile	=	640 acres

Speed

1 mile per hour (mph)	≅	1.46666667 feet per second (fps)
1 mile per hour (mph)	=	1.609344 kilometers per hour
1 knot	≅	1.150779448 miles per hour
1 foot per second	≅	0.68181818 miles per hour (mph)
1 kilometer per hour	≅	0.62137119 miles per hour (mph)

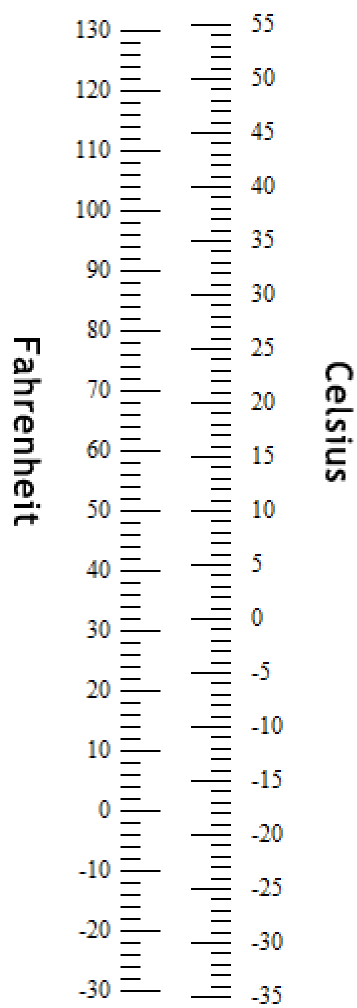
Volume

1 US tablespoon	=	3 US teaspoons
1 US fluid ounce	≅	29.57353 milliliters (ml)
1 US cup	=	16 US tablespoons
1 US cup	=	8 US fluid ounces
1 US pint	=	2 US cups
1 US pint	=	16 US fluid ounces
1 liter (l)	≅	33.8140227 US fluid ounces
1 liter (l)	=	1000 milliliters (ml)
1 US quart	=	2 US pints
1 US gallon	=	4 US quarts
1 US gallon	=	3.78541178 liters

Weight

1 milligram (mg)	=	0.001 grams (g)
1 gram (g)	=	0.001 kilograms (kg)
1 gram (g)	≅	0.035273962 ounces
1 ounce	=	28.34952312 grams (g)
1 ounce	=	0.0625 pounds
1 pound (lb)	=	16 ounces
1 pound (lb)	=	0.45359237 kilograms (kg)
1 kilogram (kg)	=	1000 grams
1 kilogram (kg)	≅	35.273962 ounces
1 kilogram (kg)	≅	2.20462262 pounds (lb)
1 stone	=	14 pounds
1 short ton	=	2000 pounds
1 metric ton	=	1000 kilograms (kg)

Temperature



Common Water Related Metric Conversions

Temperature Conversion
Metric temperature units include degrees Celsius and degrees Kelvin (degrees Celsius plus 273.1). At sea level, the freezing temperature of water is 0 degrees Celsius and the boiling point of water is 100 degrees Celsius.

The temperature unit commonly used in the US is Fahrenheit. At sea level, the freezing temperature of water is 32 degrees Fahrenheit and the boiling point of water is 212 degrees Fahrenheit.

Temperature Conversion Table		
Metric Units		**English Units**
Celsius	Kelvin	Fahrenheit
-273.1	0	-459.7
-50	223.1	-58
-40	233.1	-40
-30	243.1	-22
-20	253.1	-4
-10	263.1	14
0	273.1	32
10	283.1	50
20	293.1	68
30	303.1	86
40	313.1	104
50	323.1	122
100	373.1	212

To convert from Celsius to Fahrenheit, first multiply by 9/5, then add 32.

To convert from Fahrenheit to Celsius, first subtract 32, then multiply by 5/9

Distance or Length

Length Conversion
Metric length units include the meter, the kilometer (1,000 meters), the decimeter (0.1 meters), the centimeter (0.01 meters), the millimeter (0.001 meters), the micron (0.000001 meters), the nanometer (0.000000001 or 1e-9 meters), and the angstrom (0.0000000001 or 1e-10 meters).

The conversion for feet to meters is:

$$1 \text{ ft} = 0.3048 \text{ m}$$

So, the length conversion is to multiply by 0.3048

And the Volume Conversion must be to multiply by 0.3048, and multiply by 0.3048 and multiply by 0.3048 again:

$$30 \times 0.3048 \times 0.3048 \times 0.3048 = 0.85$$

So, **30 ft^3 = 0.85 m^3**

Length Conversion Table						
Metric Units			**English Units**			
Kilometers	Meters	Millimeters	Inches	Feet	Yards	Miles
1	1,000	1,000,000	39,370	3,281	1,094	0.6214
0.001	1	1,000	39.37	3.281	1.094	0.0006214
0.000001	0.001	1	0.03937	0.003281	0.001094	6.214e-7
0.0000254	0.0254	25.4	1	0.08333	0.02778	1.578e-5
0.0003048	0.3048	304.8	12	1	0.3333	0.0001894
0.0009144	0.9144	914.4	36	3	1	0.0005682
1.609	1,609	1,609,000	63,360	5,280	1,760	1

Area Conversion

Metric area units include the acre and the hectare (100 acres). One square kilometer is equivalent to 100 hectares.

The area unit commonly used in the USA is the acre (4840 square yards). One square mile is equivalent to 640 acres.

Area Conversion Table					
Metric Units			**English Units**		
Square Kilometers	Hectares	Ares	Square Yards	Acres	Square Miles
1	100	10,000	1,196,000	247.1	000.386
0.01	1	100	11,960	2.471	0.00386
0.0001	0.01	1	119.6	0.02471	0.0000386
8.361e-7	0.00008361	0.008361	1	0.0002066	3.228e-7
0.004047	0.4047	40.47	4,840	1	0.0015625
2.59	259	25,900	3,097,600	640	1

Area - Square feet to Meters
The conversion for feet to meters is:

$$1 \text{ ft} = 0.3048 \text{ m}$$

So the **Length** conversion is to multiply by 0.3048

And so the **Area** conversion must be to multiply by 0.3048 and multiply by 0.3048 again:

$$30 \times 0.3048 \times 0.3048 = 2.79$$

So, **30 ft^2 = 2.79 m^2**

Volume Conversion

Metric volume units include the liter, the decaliter (10 liters), the hectoliter (100 liters), the deciliter (0.1 liters), the centiliter (0.01 liters), the milliliter (0.001 liters), and the microliter (0.000001 liters. A liter is equivalent to 1 cubic decimeter.

Liquid measure units commonly used in the USA include the fluid ounce, the pint (16 fluid ounces), the quart (32 fluid ounces), the gallon (128 fluid ounces), and the petroleum barrel (5376 fluid ounces). A gallon is equivalent to 231 cubic inches.

Volume Conversion Table (Liquid Measure)				
Metric Units		**U.S. Liquid Measure Units**		
Liters	Milliliters	Fluid Ounces	Quarts	Gallons
1	1,000	33.81	1.057	0.2642
0.001	1	0.03381	0.001057	0.0002642
0.02957	29.57	1	0.03125	0.007813
0.9464	946.4	32	1	0.25
3.785	3785	128	4	1

Weight Conversion

Metric weight units include the gram, the kilogram (1,000 grams), the tonne (1,000,000 grams), the carat (0.2 grams), the centigram (0.01 grams), the milligram (0.001 grams), and the microgram (0.000001 grams).

Avoirdupois weight units commonly used in the USA include the pound, the stone (14 pounds), the short hundredweight (100 pounds), the short ton (2,000 pounds), the ounce (1/16th pound), the dram (1/256th pound), and the grain (1/7000th pound).

Weight Conversion Table					
Metric Units			**Avoirdupois Units**		
Tonnes	Kilograms	Grams	Ounces	Pounds	Short Tons
1	1,000	1,000,000	35,270	2,205	1.102
0.001	1	1,000	35.27	2.205	0.001102
0.000001	0.001	1	0.03527	0.002205	1.102e-6
0.00002835	0.02835	28.35	1	0.0625	0.00003125
0.0004536	0.4536	453.6	16	1	0.0005
0.0004536	907.2	907,200	32,000	2,000	1

General Math Concepts

Addition Review Section

Addition is a mathematical operation that represents the total amount of objects together in a collection. It is signified by the plus sign (+). For example, if there are 3 + 2 oranges—meaning three oranges and two oranges together, there is a total of 5 oranges.

Therefore, 3 + 2 = 5.

Besides counting fruits, addition can also represent combining other physical and abstract quantities using different kinds of objects: negative numbers, fractions, irrational numbers, vectors, decimals, functions, matrices and more.

Addition has several important properties. It is commutative, meaning that order does not matter, and it is associative, meaning that when one adds more than two numbers, the order in which addition is performed does not matter (see *Summation*).

Repeated addition of 1 is the same as counting; addition of 0 does not change a number. Addition also obeys predictable rules concerning related operations such as subtraction and multiplication.

Performing addition is one of the simplest numerical tasks. Addition of very small numbers is accessible to toddlers; the most basic task, 1 + 1, can be performed by infants as young as five months and even some animals. In primary education, students are taught to add numbers in the decimal system, starting with single digits and progressively tackling more difficult problems.

A simple addition problem usually looks like this

3+4=7

The + sign is called a plus sign. This sign means add.

The = is called an equal sign. This shows the answer to the problem you have just completed. Both the 3 and the 4 are called addends in addition. The two number s that will be added. The 7 in this problem is called the sum. The sum is the answer you got to by adding two or more numbers together.

Summation is the operation of adding a sequence of numbers; the result is their **sum** or *total*. If numbers are added sequentially from left to right, any intermediate result is a partial sum, prefix sum, or running total of the summation.

The numbers to be summed (called **addends**, or sometimes **summands**) may be integers, rational numbers, real numbers, or complex numbers. Besides numbers, other types of values can be added as well: vectors, matrices, polynomials and, in general, elements of any additive group (or even monoid). For finite sequences of such elements, summation always produces a well-defined sum (possibly by virtue of the convention for empty sums).

Addition Table

+	0	1	2	3	4	5	6	7	8	9	10
0	0	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10	11
2	2	3	4	5	6	7	8	9	10	11	12
3	3	4	5	6	7	8	9	10	11	12	13
4	4	5	6	7	8	9	10	11	12	13	14
5	5	6	7	8	9	10	11	12	13	14	15
6	6	7	8	9	10	11	12	13	14	15	16
7	7	8	9	10	11	12	13	14	15	16	17
8	8	9	10	11	12	13	14	15	16	17	18
9	9	10	11	12	13	14	15	16	17	18	19
10	10	11	12	13	14	15	16	17	18	19	20

There are also situations where addition is "understood" even though no symbol appears:

- A column of numbers, with the last number in the column underlined, usually indicates that the numbers in the column are to be added, with the sum written below the underlined number.
- A whole number followed immediately by a fraction indicates the sum of the two, called a *mixed number*. For example,
  3½ = 3 + ½ = 3.5.

- This notation can cause confusion since in most other contexts juxtaposition denotes multiplication instead.

Adding 10 plus 10 and reaching a conclusion of 20 is a simple operation, but adding complex numbers like 13.333 and 0.0033 pose a larger challenge. Follow these basic rules to avoid arriving at incorrect answers when adding complex numbers:

Step 1: Decimal points and numbers should line up in columns. When this rule is followed correctly, the addition problem is easily solved.

13.3330	32 inches	2.666 feet
+0.0033	+42 inches	+3.500 feet
13.3363	74 inches	6.166 feet

Step 2: Be sure you are not adding apples and oranges. All numbers must represent the same type of units, i.e. inches, pounds, feet. For example, in adding the length of two pieces of pipe, if one is 32 inches and the other is 3 feet, you must convert to common units.

First divide 32 inches by 12 to convert to 2.66 feet or multiply 3 feet by 12 to convert to 36 inches before adding the numbers.

Step 3: When doing math without a calculator, make sure to write down the numbers that carry over when adding. See example below.

$$\begin{array}{r} \mathit{11} \\ \mathbf{687} \\ \underline{\mathbf{+\ 687}} \\ \mathbf{1374} \end{array}$$

Basic Rules for Performing Calculations
There are four general rules to remember when performing calculations:
We will only cover the first one.

Rule 1: Perform calculations from left to right.

Advanced Addition

Addition of Natural and Real Numbers
To prove the usual properties of addition, one must first *define* addition for the context in question. Addition is first defined on the natural numbers. In set theory, addition is then extended to progressively larger sets that include the natural numbers: the integers, the rational numbers, and the real numbers (In mathematics education, positive fractions are added before negative numbers are even considered; this is also the historical route).

Natural Numbers
In mathematics, the **natural numbers** are those used for counting ("there are five coins on the table") and ordering ("this is the second largest city in the country"). These purposes are related to the linguistic notions of cardinal and ordinal numbers, respectively. A later notion is that of a nominal number, which is used only for naming.

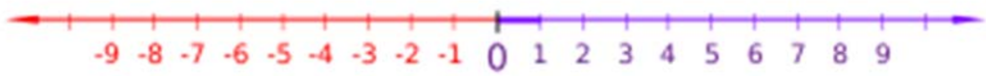
Properties of the natural numbers related to divisibility, such as the distribution of prime numbers, are studied in number theory. Problems concerning counting and ordering, such as partition enumeration, are studied in combinatorics.

There is no universal agreement about whether to include zero in the set of natural numbers. Some authors begin the natural numbers with 0, corresponding to the *non-negative integers* {0, 1, 2, 3, ...}, whereas others start with 1, corresponding to the *positive integers* {1, 2, 3, ...}.

Real Number
In mathematics, a **real number** is a value that represents a quantity along a continuous line. The real numbers include all the rational numbers, such as the integer −5 and the fraction 4/3, and all the irrational numbers such as $\sqrt{2}$ (1.41421356…, the square root of two, an irrational algebraic number) and π (3.14159265…, a transcendental number).

Real numbers can be thought of as points on an infinitely long line called the number line or real line, where the points corresponding to integers are equally spaced. Any real number can be determined by a possibly infinite decimal representation such as that of 8.632, where each consecutive digit is measured in units one tenth the size of the previous one.

The real line can be thought of as a part of the complex plane, and complex numbers include real numbers.



Real numbers can be thought of as points on an infinitely long number line.

Adding Decimals

Decimals are fractional numbers. The decimal 0.4 is the same as the fraction 4/10. The number 0.69 is a decimal that represents 69/100.

Adding Decimals is just like adding other numbers.

Always line up the decimal points when adding decimals.

The prerequisite to addition in the decimal system is the fluent recall or derivation of the 100 single-digit "addition facts".

One could memorize all the facts by rote, but pattern-based strategies are more enlightening and, for most people, more efficient:

- *Commutative property*: Mentioned above, using the pattern $a + b = b + a$ reduces the number of "addition facts" from 100 to 55.

- *One or two more*: Adding 1 or 2 is a basic task, and it can be accomplished through counting on or, ultimately, intuition.

- *Zero*: Since zero is the additive identity, adding zero is trivial. Nonetheless, in the teaching of arithmetic, some students are introduced to addition as a process that always increases the addends; word problems may help rationalize the "exception" of zero.

- *Doubles*: Adding a number to itself is related to counting by two and to multiplication. Doubles facts form a backbone for many related facts, and students find them relatively easy to grasp.

- *Near-doubles*: Sums such as 6+7=13 can be quickly derived from the doubles fact 6+6=12 by adding one more, or from 7+7=14 but subtracting one.

- *Five and ten*: Sums of the form 5+x and 10+x are usually memorized early and can be used for deriving other facts. For example, 6+7=13 can be derived from 5+7=12 by adding one more.

- *Making ten*: An advanced strategy uses 10 as an intermediate for sums involving 8 or 9; for example, 8 + 6 = 8 + 2 + 4 = 10 + 4 = 14.

Decimal Addition Exercise *Answers are provided.*

1 a. 0.0 + 0.1 = ________

1 b. 0.50 + 0.574 = _______

2 a. 0.5 + 0.84 = _______

2 b. 0.80 + 0.97 = _______

3 a. 0.49 + 0.00 = _______

3 b. 0.8 + 0.8 = _______

4 a. 0.27 + 0.58 = _______

4 b. 0.91 + 0.799 = _______

5 a. 0.8 + 0.98 = _______

5 b. 0.144 + 0.25 = _______

6 a. 0.3 + 0.12 = ________

6 b. 0.38 + 0.16 = ________

7 a. 0.9 + 0.6 = ________

7 b. 0.92 + 0.13 = ________

8 a. 0.142 + 0.1 = ________

8 b. 0.0 + 0.7 = ________

9 a. 0.0 + 0.980 = ________

9 b. 0.034 + 0.03 = ________

10 a. 0.71 + 0.46 = ________

10 b. 0.6 + 0.6 = ________

Answers 1a. 0.1, 2a. 1.34, 3a. 0.49, 4a. 0.85, 5a. 1.78, 6a. 0.42, 7a. 1.5, 8a. 0.242, 9a. 0.980, 10a. 1.17
1b. 1.074, 2b. 1.77, 3b. 1.6, 4b. 1.709, 5b. 0.394, 6b. 0.54, 7b. 1.05, 8b. 0.7, 9b. 0.064, 10b. 1.2

Subtraction Review

Subtraction is a mathematical operation that represents the operation of removing objects from a collection. It is signified by the minus sign (−). For example, there are 7 − 2 oranges—meaning 7 oranges with 2 taken away, which is a total of 5 oranges.

Therefore, $7 - 2 = 5$.

Or in addition $2+5 = 7$

Besides counting fruits, subtraction can also represent combining other physical and abstract quantities using different kinds of objects: negative numbers, fractions, irrational numbers, vectors, decimals, functions, matrices and more.

Subtraction follows several important patterns. It is anti-commutative, meaning that changing the order changes the sign of the answer. It is not associative, meaning that when one subtracts more than two numbers, the order in which subtraction is performed matters.

Subtraction of 0 does not change a number. Subtraction also obeys predictable rules concerning related operations such as addition and multiplication. All of these rules can be proven, starting with the subtraction of integers and generalizing up through the real numbers and beyond. General binary operations that continue these patterns are studied in abstract algebra.

Subtraction is simply taking one number away from the other. It's pretty straightforward when you're subtracting one whole number from another, but subtraction can get a bit more complicated when you're working with fractions or decimals.

Once you get the hang of subtraction, you'll be able to move on to more complicated mathematical concepts, and will be able to add, multiply, and divide numbers with greater ease.

The traditional names for the parts of the formula

$a - b = c$

Where the minuend (a) - subtrahend (b) = difference (c).

Subtraction as Addition
There are some cases where subtraction as a separate operation becomes problematic. For example, $3 - (-2)$ (i.e. subtract −2 from 3) is not immediately obvious from either a natural number view or a number line view, because it is not immediately clear what it means to move −2 steps to the left or to take away −2 apples.

One solution is to view subtraction as addition of signed numbers.

Extra minus signs simply denote additive inversion. Then we have $3 - (-2) = 3 + 2 = 5$. This also helps to keep the ring of integers "simple" by avoiding the introduction of "new" operators such as subtraction. Ordinarily a ring only has two operations defined on it; in the case of the integers, these are addition and multiplication.

Subtraction Table

Use this subtraction table to get an answer for some basic subtraction problems

When using the table, look first for a number in the leftmost column

Then, subtract from that number by selecting a number in the top horizontal row

The answer can be found where the column and row meet.

For instance, 8 (in the vertical column) minus 9 (in the horizontal row) = -1

−	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
0	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
1	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11
2	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
3	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9
4	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8
5	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7
6	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6
7	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5
8	8	7	6	5	4	3	2	1	0	-1	-2	-3	-4
9	9	8	7	6	5	4	3	2	1	0	-1	-2	-3
10	10	9	8	7	6	5	4	3	2	1	0	-1	-2

Subtraction Review Section

Step 1: Make sure all decimals are in line. Unlike adding a carryover like we did for addition you may need to borrow.

13.333	42 inches	3.500 feet
-3.333	-32 inches	-2.200 feet
10.000	10 inches	1.300 feet

Step 2: Having to borrow when the top unit is less than the bottom.
For example:

```
 374
-286

 2  16
 3  17  14
-2   8   6
     8   8
```

1. (One's column) - Borrow one unit (10) from the 7 in the tens column. You now subtract 6 from 14 to get 8 in the ones column.
2. (Column two) – Since you borrowed one unit from the seven, which leaves six, you must now borrow one unit (100) from the one hundred's column. You now subtract 8 from 16 to get 8 in the tens column.
3. After borrowing from the one hundred's column you are left with a 2 in that column. Subtracting 2 from 2 is equal to zero. No entry is needed in the thousand's column.

Practice writing the problem out like the previous examples. This will help you when we begin solving problems that relate to our industry. **Answers are provided.**

A. 12 + 54 =

B. 15 + 13 =

C. 23.2 + 12.6 =

D. 25.32 + 23.06 =

E. 4.36 + 102 =

F. 23.5 + 14.32 + 12.444 =

G. 123.45 + 2.3 + 10.1234 =

H. 0.32597 + 2.684 + 18.364 =

I. 0.36 + 0.026 + 0.005 =

J. 1.3 + 0.223 + 1.445 =

K. 72 – 54 =

L. 1.5 – 1.3 =

M. 23 – 12.6 =

N. 18.36 – 18.36 =

O. 9.5 – 6.25 =

P. 67.89 – 10.1 – 3.142 =

Q. 6.334 – 0.087 =

R. 8.335 – 3.2589 – 1.3 =

S. 100.23 – 5.34 – 6.789 =

T. 137.1 – 34 – 19.56 =

Answers 1. 66, 2. 28, 3. 35.8, 4. 48.38, 5. 106.36, 6. 50.264, 7. 135.8734, 8. 21.37397, 9. 0.391, 10. 2.986, 11. 18, 12. 0.2, 13. 10.4, 14. 15.676, 15. 3.25,16. 54.648,17. 6.247,18. 3.7761, 19. 88.101 20. 83.54

Rounding Decimals
Find the place value you want (the "rounding digit") and look at the digit just to the right of it. If that digit is less than 5, do not change the rounding digit but drop all digits to the right of it.

If that digit is greater than 5, add one to the rounding digit and drop all digits to the right of it.

If the digit is 5, round to the even number. At times this will result in rounding up and at other times, rounding down. It is theorized that the frequency of rounding up will equal the times rounded down.

Multiplication Review Section

Multiplication (often denoted by the cross symbol "**×**", or by the absence of symbol) is the third basic mathematical operation of arithmetic, the others being addition, subtraction and division (the division is the fourth one, because it requires multiplication to be defined).

The multiplication of two whole numbers is equivalent to the addition of one of them with itself as many times as the value of the other one; for example, 3 multiplied by 4 (often said as "3 times 4") can be calculated by adding 3 copies of 4 together:

$$3 \times 4 = 4 + 4 + 4 = 12$$

Here 3 and 4 are the "factors" and 12 is the "product".

One of the main properties of multiplication is that the result does not depend on the place of the factor that is repeatedly added to itself (commutative property). 3 multiplied by 4 can also be calculated by adding 4 copies of 3 together:

$$3 \times 4 = 3 + 3 + 3 + 3 = 12$$

For example, since 4 multiplied by 3 equals 12, then 12 divided by 3 equals 4. Multiplication by 3, followed by division by 3, yields the original number (since the division of a number other than 0 by itself equals 1).

The multiplication of integers (including negative numbers), rational numbers (fractions) and real numbers is defined by a systematic generalization of this basic definition.

Before we get started you need to be aware of what is called “The order of operation”.

Order of Operations	
( ) , [ ] , { }	Parentheses, Brackets, Braces
x^a , $\sqrt{}$	Exponents, radicals
× , ÷	Multiplication, Division
+ , −	Addition, Subtraction

There are a few steps to remember before you begin to multiply for instance how the symbols are presented and decimal positions:

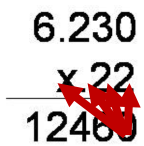
5 x 2 = 10

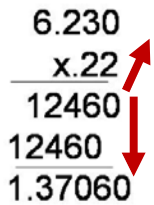
5 * 2 = 10

(5)(2) = 10

Before Calculators

```
  6.230
   x.22
  12460
 12460
1.37060
```





Because the second 2 is in the tenth column 2 x 0 answer also starts in the tenth column. The position of the decimal place is dependent on the position. You add the position, right to left, and depending on how many rows to multiply, you simply add them up.

The example shows the decimal point three places to the right on the top row and two places to the right on the second which is a total of five places to move the decimal over for your final answer. 137060 becomes 1.37060, a big difference.

Multiplication can also be visualized as counting objects arranged in a rectangle (for whole numbers) or as finding the area of a rectangle whose sides have given lengths.

The area of a rectangle does not depend on which side is measured first, which illustrates the commutative property.

In general, multiplying two measurements gives a new type, depending on the measurements.

For instance:

3.5 Meters X 4.5 Meters = 15.75 Square Meters

12 Meters/Sec X 12 Seconds = 144 Meters

The inverse operation of the multiplication is the division.

Multiplication is also defined for other types of numbers, such as complex numbers, and more abstract constructs, like matrices.

For these more abstract constructs, the order that the operands are multiplied sometimes does matter.

In water arithmetic, multiplication is often written using the multiplication sign "×" but ˙ is most common between the terms, as infix notation. See below.

For example,

2 x 5   (verbally, "TWO times FIVE equals TEN")

3 X 4 =12

2 X 2 X 3 = 12

2 X 3 X 4 X 5 = 120

Multiplication is sometimes denoted by dot signs, either a middle-position dot or a period:

6 ˙ 2 or 6 . 2

In his 1820 book *The Philosophy of Arithmetic*, mathematician John Leslie published a multiplication table up to 99 × 99, which allows numbers to be multiplied in pairs of digits at a time. Leslie also recommended that young pupils memorize the multiplication table up to 25 × 25.

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
3	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
4	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
6	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
7	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140
8	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160
9	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180
10	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
11	11	22	33	44	55	66	77	88	99	110	121	132	143	154	165	176	187	198	209	220
12	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240
13	13	26	39	52	65	78	91	104	117	130	143	156	169	182	195	208	221	234	247	260
14	14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280
15	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
16	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320
17	17	34	51	68	85	102	119	136	153	170	187	204	221	238	255	272	289	306	323	340
18	18	36	54	72	90	108	126	144	162	180	198	216	234	252	270	288	306	324	342	360
19	19	38	57	76	95	114	133	152	171	190	209	228	247	266	285	304	323	342	361	380
20	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400

The traditional rote learning of multiplication was based on memorization of columns in the table, in a form like

1 × 10 = 10
2 × 10 = 20
3 × 10 = 30
4 × 10 = 40
5 × 10 = 50
6 × 10 = 60
7 × 10 = 70
8 × 10 = 80
9 × 10 = 90

1 · 10 = 10
2 · 10 = 20
3 · 10 = 30
4 · 10 = 40
5 · 10 = 50
(6 10) = 60
(7 × 10) = 70
(8 × 10) = 80
(9 × 10) = 90

In algebra, multiplication involving variables is often written as a juxtaposition (e.g., *xy* for *x* times *y* or 5*x* for five times *x*). This notation can also be used for quantities that are surrounded by parentheses (e.g., 5(2) or (5)(2) for five times two).

In matrix multiplication, there is actually a distinction between the cross and the dot symbols. The cross symbol generally denotes a vector multiplication, while the dot denotes a scalar multiplication. A similar convention distinguishes between the cross product and the dot product of two vectors.

Basic Rules for Performing Calculations
There are four general rules to remember when performing calculations: We will cover three for now.

Rule 1: Perform calculations from left to right.

Rule 2: Perform all arithmetic within parentheses prior to arithmetic outside the parentheses

Rule 3: Perform all multiplication and division prior to performing all addition and subtraction.

Related Operations

Arithmetic
Subtraction can be thought of as a kind of addition—that is, the addition of an additive inverse. Subtraction is itself a sort of inverse to addition, in that adding *x* and subtracting *x* are inverse functions.

Given a set with an addition operation, one cannot always define a corresponding subtraction operation on that set; the set of natural numbers is a simple example. On the other hand, a subtraction operation uniquely determines an addition operation, an additive inverse operation, and an additive identity; for this reason, an additive group can be described as a set that is closed under subtraction.

Order of Operation Review

Order of Operations	
( ) , [ ] , { }	Parentheses, Brackets, Braces
x^a , $\sqrt{\ }$	Exponents, radicals
× , ÷	Multiplication, Division
+ , −	Addition, Subtraction

Solve the problem below using the order of operation. We will take one step at a time using the order of operation.

[12 –(3+2) (3-1)] [8+(6-2)] = 24

Step 1: The first order is to solve all brackets in bold in the above. The next order is addition and then subtraction:

[12 – (5)(2)] Notice that the 5 and 2 or next to each other because of the parentheses? That means they need to be multiplied according to the order of operation.

Now you are left with:

[12 – 10] this equals [2]

Step 2: Take the next set of brackets and apply the order of operation. This time the number 6 is being subtracted by 2 in the parentheses:

[8+(6-2)]

[8+4] = [12]

What we have left is: **[2] [12] = 24!**

Sometimes multiplication may have a specific unit attached to it.

For example:

4 men X 3 hours = 12 man-hours

Multiplication can be thought of as repeated addition. If a single term *x* appears in a sum *n* times, then the sum is the product of *n* and *x*. If *n* is not a natural number, the product may still make sense; for example, multiplication by −1 yields the additive inverse of a number.

Multiplication Practice Exercise #1

Practice writing the problem out as with the previous examples. Writing out the problem will help you when we begin solving problems that relate to our industry.
Answers are provided

A. 15 x 13 =

B. 23.3 x 12.6 =

C. 14.51 x 12.3 =

D. 12.3 x 39.005 =

E. 67.89 x 10.1 =

F. 3.259 x 8.3 =

G. 3.21 x 6.334 =

H. 2.684 x 18.364 x (3 + 2) =

I. (9 + 1) x (4 + 9) =

J. (12 + 2) x 13 =

K. 311÷12 =

L. 25 ÷ 3 =

M. 250 ÷ 10 =

N. 1 ÷ 3 =

O. 6 ÷ 12 =

For the following numbers, you can use a calculator just make sure you put the number on the left in first. In the expression a ÷ b = c, *a* is called the **dividend** or **numerator**, *b* the **divisor** or **denominator** and the result *c* is called the **<u>quotient</u>**.

P. 0.67 ÷ 0.7 =

Q. 12.54 ÷ 1.5 =

R. 25 ÷ (10 + 2) =

S. (25 x 10) ÷ 12 =

T. (25 x 10) ÷ (10 + 2) =

Answers

A. 195
B. 293.58
C. 178.473
D. 479.7615 or 479.762
E. 685.689
F. 27.0497
G. 20.33214
H. 246.44488 or 246.445
I. 130
J. 182
K. 25.9167 or 25.917
L. 8.33
M. 25
N. 0.33
O. 0.5
P. 0.957
Q. 8.36
R. 2.083
S. 20.83
T. 20.83

Would this mistake benefit your checking account?

The Bank Deposited

Amount Deposited
253.25
15.95
86.73
5.00
Total: 36.093

Your Correct Deposit

Amount Deposited
253.25
15.95
86.73
5.00
Total: 360.93

- Which is closer to a whole number?
  A. 0.1001
  B. 0.0433389
  C. 0.0669
  D. 0.9

? If the MCL for a contaminate is 0.050 mg/L and your lab result is 0.06 mg/L are you in violation? **YES**

"Rounding up is not always a benefit"

Averages Review Section

Sometimes in our industry the word "Means" is used instead of average, to keep it simple it's just about the same meaning. Most of us will know how to find the mathematical average or mean of a set of numbers.

Average = Sum of Numbers / Quantity of Numbers.

For example, the following chlorine use in pounds was used for each day for a week. What is the average amount used per day?

Monday	8.2
Tuesday	7.9
Wednesday	6.3
Thursday	6.5
Friday	7.4
Saturday	6.2
Sunday	5.9

Add all the numbers then divide it by the numbers of days:

8.2+7.9+6.3+6.5+7.4+6.2+5.9 = 48.4 / 7 = 6.9

Given the following flow rates, what is the average flow for a 24 hour period?

Time	MGD
0:00	1.18
2:00	1.31
4:00	1.25
6:00	1.33
8:00	1.31
10:00	1.22
12:00	1.13
14:00	1.54
16:00	1.69
18:00	1.75
20:00	1.67
22:00	1.22

If you get 1.38 for an answer - congratulations!

The Figure the Flow Average

$$\text{Average Daily Discharge} = \frac{(Q1 + Q2 + Q3 + \dots QN)}{N}$$

Where Q is the flow measured at any given time during the day, and N is the number of times the flow is measured.

Example

Q1 = 5.3 MGD
Q2 = 5.7 MGD
Q3 = 5.5 MGD
Q4 = 5.1 MGD

$$\text{Daily Discharge} = \frac{(5.3 + 5.7 + 5.5 + 5.1)}{4} = 5.4 \text{ MGD}$$

$$\text{Average Weekly Discharge} = \frac{(Q1 + Q2 + Q3 + \dots Q7)}{N}$$

Where Q is the daily discharge for days that flow is measured, and N is the number of days in the week (7) that flow is measured.

$$\text{Average Monthly Discharge} = \frac{(Q1 + Q2 + Q3 + \dots Q31)}{N}$$

Where Q is the daily discharge for the days that flow is measured, and N is the number of days in the month that flow is measured.

Basic Rules for Performing Calculations
There are four general rules to remember when performing calculations:
Rule 1: Perform calculations from left to right.

Rule 2: Perform all arithmetic within parentheses prior to arithmetic outside the parentheses.

Rule 3: Perform all multiplication and division prior to performing all addition and subtraction.

Rule 4: For complex division problems follow the previous rules starting with parenthesis. Next perform all multiplication and division above the line (in the numerator) and below the line (in the denominator); then proceed with the addition and subtraction. Finally divide the numerator by the denominator.

Division Review Section

Division is the opposite of multiplication. When we multiply we think BIG! When we divide the number will be getting smaller.

In mathematics, especially in elementary arithmetic, **division** (÷) is an arithmetic operation.

Specifically, if *b* times *c* equals *a*, written:

$$a = b \times c$$

where *b* is not zero, then *a* divided by *b* equals *c*, written:

$$a \div b = c$$

For instance,

$$8 \div 4 = 2$$

since

$$4 \times 2 = 8$$

In the expression a ÷ b = c, *a* is called the **dividend** or **numerator**, *b* the **divisor** or **denominator** and the result *c* is called the **quotient**.

Division can also be written in several ways.

For example:

12 men ÷ 2 hours = 6 man-hours

or

(12 men) **/** (2 hours)

or

$\frac{\text{12 men}}{\text{2 hours}}$

$$\frac{12}{2} = 6$$

$$2\overline{)12} = 6$$

Using the order of operation and putting division in the problem let's solve for the following:

[(10-3) (7+2)] / [(3)(2)] =

[(7)(9)] **/** 6

63 divided by 6 = 10.5

Notice the .5, this answer comes from a calculator. If you did this as a written problem, it would be a remainder of 5. For example:

```
     10.5
6  ) 63.0
    -6
    030
```

6 goes into 6, 1 time, 6-6 = 0. 6 goes into 3 zero times, which leaves three, now we need to add a zero and a decimal. 6 goes into 30, 5 times.

Teaching division usually leads to the concept of fractions being introduced to school pupils. Unlike addition, subtraction, and multiplication, the set of all integers is not closed under division. Dividing two integers may result in a remainder. To complete the division of the remainder, the number system is extended to include fractions or rational numbers as they are more generally called.

Notation

Division is often shown in algebra and science by placing the *dividend* over the *divisor* with a horizontal line, also called a vinculum or fraction bar, between them. For example, *a* divided by *b* is written

$$\frac{a}{b}$$

This can be read out loud as "a divided by b", "a by b" or "a over b". A way to express division all on one line is to write the *dividend* (or numerator), then a slash, then the *divisor* (or denominator), like this:

$$a/b$$

This is the usual way to specify division in most computer programming languages since it can easily be typed as a simple sequence of ASCII characters. Some mathematical software, such as GNU Octave, allows the operands to be written in the reverse order by using the backslash as the division operator:

$$b/a$$

Significant Number

The **significant figures** of a number are those digits that carry meaning contributing to its precision. Numbers are often rounded to avoid reporting insignificant figures. Numbers can also be rounded merely for simplicity rather than to indicate a given precision of measurement, for example to make them faster to pronounce for water treatment purposed or distribution delivery.

Rounding up

The best rule of thumb is to keep all numbers because they all have a value after the decimal point, however we usually keep <u>three significant numbers</u> after the decimal point.

For example:

21.37397 if the fourth number is over 5 round the next number up.

21.37**4**

Division of Integers

Conceptually, division of integers can be viewed in either of two distinct but related ways quotition and partition:

- **Partitioning** involves taking a set of size *a* and forming *b* groups that are equal in size. The size of each group formed, *c*, is the quotient of *a* and *b*.

- **Quotition**, or **quotative division** (also sometimes spelled *quotitive*) involves taking a set of size *a* and forming groups of size *b*. The number of groups of this size that can be formed, *c*, is the quotient of *a* and *b*. (Both divisions give the same result because multiplication is commutative.)

Basic Rules for Performing Calculations

There are four general rules to remember when performing calculations:

Rule 1: Perform calculations from left to right.

Rule 2: Perform all arithmetic within parentheses prior to arithmetic outside the parentheses

Rule 3: Perform all multiplication and division prior to performing all addition and subtraction.

Rule 4: For complex division problems follow the previous rules starting with parenthesis. Next perform all multiplication and division above the line (in the numerator) and below the line (in the denominator); then proceed with the addition and subtraction. Finally divide the numerator by the denominator.

Division Table

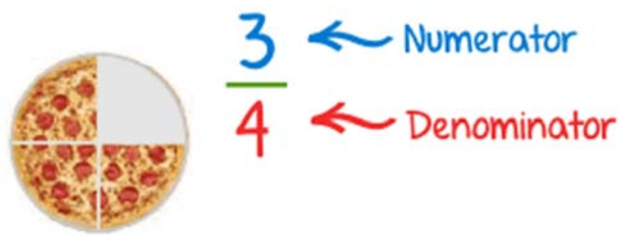
Division by 1	Division by 2	Division by 3	Division by 4	Division by 5
1 ÷ 1 = 1	2 ÷ 2 = 1	3 ÷ 3 = 1	4 ÷ 4 = 1	5 ÷ 5 = 1
2 ÷ 1 = 2	4 ÷ 2 = 2	6 ÷ 3 = 2	8 ÷ 4 = 2	10 ÷ 5 = 2
3 ÷ 1 = 3	6 ÷ 2 = 3	9 ÷ 3 = 3	12 ÷ 4 = 3	15 ÷ 5 = 3
4 ÷ 1 = 4	8 ÷ 2 = 4	12 ÷ 3 = 4	16 ÷ 4 = 4	20 ÷ 5 = 4
5 ÷ 1 = 5	10 ÷ 2 = 5	15 ÷ 3 = 5	20 ÷ 4 = 5	25 ÷ 5 = 5
6 ÷ 1 = 6	12 ÷ 2 = 6	18 ÷ 3 = 6	24 ÷ 4 = 6	30 ÷ 5 = 6
7 ÷ 1 = 7	14 ÷ 2 = 7	21 ÷ 3 = 7	28 ÷ 4 = 7	35 ÷ 5 = 7
8 ÷ 1 = 8	16 ÷ 2 = 8	24 ÷ 3 = 8	32 ÷ 4 = 8	40 ÷ 5 = 8
9 ÷ 1 = 9	18 ÷ 2 = 9	27 ÷ 3 = 9	36 ÷ 4 = 9	45 ÷ 5 = 9
10 ÷ 1 = 10	20 ÷ 2 = 10	30 ÷ 3 = 10	40 ÷ 4 = 10	50 ÷ 5 = 10

Division by 6	Division by 7	Division by 8	Division by 9	Division by 10
6 ÷ 6 = 1	7 ÷ 7 = 1	8 ÷ 8 = 1	9 ÷ 9 = 1	10 ÷ 10 = 1
12 ÷ 6 = 2	14 ÷ 7 = 2	16 ÷ 8 = 2	18 ÷ 9 = 2	20 ÷ 10 = 2
18 ÷ 6 = 3	21 ÷ 7 = 3	24 ÷ 8 = 3	27 ÷ 9 = 3	30 ÷ 10 = 3
24 ÷ 6 = 4	28 ÷ 7 = 4	32 ÷ 8 = 4	36 ÷ 9 = 4	40 ÷ 10 = 4
30 ÷ 6 = 5	35 ÷ 7 = 5	40 ÷ 8 = 5	45 ÷ 9 = 5	50 ÷ 10 = 5
36 ÷ 6 = 6	42 ÷ 7 = 6	48 ÷ 8 = 6	54 ÷ 9 = 6	60 ÷ 10 = 6
42 ÷ 6 = 7	49 ÷ 7 = 7	56 ÷ 8 = 7	63 ÷ 9 = 7	70 ÷ 10 = 7
48 ÷ 6 = 8	56 ÷ 7 = 8	64 ÷ 8 = 8	72 ÷ 9 = 8	80 ÷ 10 = 8
54 ÷ 6 = 9	63 ÷ 7 = 9	72 ÷ 8 = 9	81 ÷ 9 = 9	90 ÷ 10 = 9
60 ÷ 6 = 10	70 ÷ 7 = 10	80 ÷ 8 = 10	90 ÷ 9 = 10	100 ÷ 10 = 10

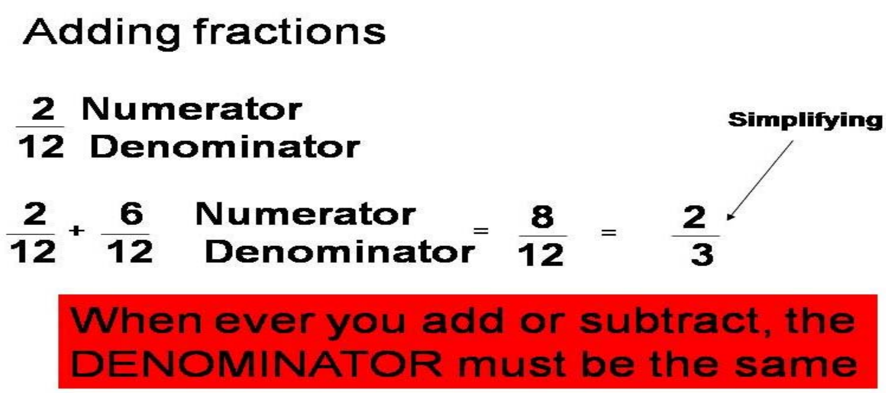
- ✓ Dividing by 0 is not allowed.
- ✓ Zero divided by every number results to zero.

Fractions

Keep in mind that a fraction is part or percentage of something whole, like the pizza below.



Division Terms
In the expression a ÷ b = c, *a* is called the **dividend** or **numerator**, *b* the **divisor** or **denominator** and the result *c* is called the **quotient**.



Same Denominator
A common denominator is when two or more fractions have the same denominator, such as the number 12 above. The denominators must be the same before you can add or subtract the fractions. You can find a common denominator by trying different multiples of the fractions.

For instance:

2/3 + 1/4 = ?

Because the denominator is uncommon, think of a number that they would both multiply into.

3 in (2/3) will multiply by 4 to equal 12 and 4 in (1/4) will multiply by 3 to also equal 12.

12 is the denominator. But there is one more step. If I multiplied 3 x 4 in (2/3) I need to multiply 4 x 2 = 8 so know my 2/3 is now 8/12 and the same goes for the other fraction.

8/12 + 3/12 = 11/12 as you can see we only add the numerator. To simplify you would do the same process in finding a denominator, however 11/12 is as simple as it gets.

Subtraction of Fractions

Same concept as adding fractions except you subtract the numerator.

$$8/12 - 3/12 = 5/12$$

Improper Fractions

Let's look at that pizza again.

You can see that three slices are present but one slice is missing. The written fraction of what is missing can be expressed ¼ or 0.25.

What makes an improper fraction is when the numerator is greater than the denominator.

For example 12/4, if the pizza is cut in four pieces you can't take twelve slices. What 12/4 really represents is 12 divided by 4 which give you 3 whole pizzas.

Simplify or Reduce

To reduce a fraction to its lowest terms divide the numerator and denominator by the largest number that equally divides into both of them.

For example 10/30**:** 10 = 10 ÷ 10 = 1

30 = 30 ÷ 10 = 3

Note: Dividing or multiplying both the numerator and denominator by the same number does not change the value of the fraction. It is the equivalent of dividing or multiplying by 1 (one).

For example: 10/10 = 1

With complex fractions, it may not be easy to determine the largest number that equally divides into both the numerator and denominator. In this case, determine a number (factor) that will divide evenly into both. Continue this process until it can no longer be performed by a number larger than one.

For example **256/288:**

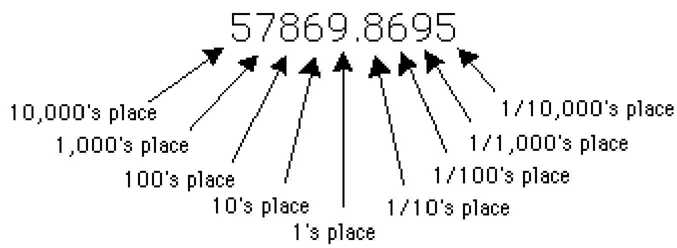
$$256 \div 2 = 128 \div 2 = 64 \div 8 = 8$$

288 ÷ 2 = 144 ÷ 2 = 72 ÷ 8 = 9

Final answer, 256/288 is equal to 8/9.

Percentage and Fraction Review
Let's look again at the sequence of numbers 1000, 100, 10, 1, and continue the pattern to get new terms by dividing previous terms by 10:

.1 = 1/10
.01 = 1/100
.001 = 1/1000



So just as the digits to the left of the decimal represent 1's, 10's, 100's, and so forth, digits to the right of the decimal point represent 1/10's, 1/100's, 1/1000's, and so forth. Let's express 5% as a decimal. 5 ÷ 100 = 0.05 or you can move the decimal point to the left two places.

Changing a fraction to a decimal:
Divide the numerator by the denominator

A. 5/10 (five tenths) = five divided by ten:

```
        .5
       -----
  10 ) 5.0
       5 0
```

5/10 (five tenths) = .5 (five tenths).

B. How about 1/2 (one half) or 1 divided by 2 ?

```
       .5
      -----
  2 ) 1.0
      1 0
```

1/2 (one half) = .5 (five tenths)
Notice that equivalent fractions convert to the same decimal representation.

8/12 is a good example. 8 ÷ 12 =.66666666 or rounded off to .667

Again, in the expression a ÷ b = c, *a* is called the **dividend** or **numerator**, *b* the **divisor** or **denominator** and the result *c* is called the **quotient**.

Multiplying Fractions

Multiply all numerators together to arrive at a new numerator and multiply all denominators together to arrive at a new denominator. The example below shows how to multiply and how to simplify using cross cancellation.

$$\frac{2}{4} \times \frac{3}{6} \times \frac{4}{5} = \frac{(2)(3)(4)}{(4)(6)(5)} = \frac{24}{120}$$

Simplify using cross cancellation

$$\frac{\overset{1}{\cancel{2}}}{\underset{1}{\cancel{4}}} \times \frac{3}{\underset{3}{\cancel{6}}} \times \frac{\overset{1}{\cancel{4}}}{5} = \frac{(1)(3)(1)}{(1)(3)(5)} = \frac{3}{15}$$

Dividing Fractions

$$\frac{2}{4} \div \frac{3}{6} \div \frac{4}{5} = \frac{2}{4} \times \frac{6}{3} \times \frac{5}{4}$$

Divisor ($\frac{2}{4}$)

When you divide, the divisor stays the same and the others are inverted (flip em)

Simplify using cross cancellation

$$\frac{\overset{1}{\cancel{2}}}{\underset{2}{\cancel{4}}} \times \frac{\overset{3}{\cancel{6}}}{3} \times \frac{5}{\underset{2}{\cancel{4}}} = \frac{(1)(3)(5)}{(2)(3)(2)} = \frac{15}{12}$$

Decimal Section

Another method of representing a fraction is by using decimals of tenths, hundredths, and so forth. This is a much easier method especially if you use a calculator. Keep in mind a "Fraction of a Whole" and "What Percent of a Whole" is what we are trying to achieve. If you have a fraction and want to convert it to a decimal, you should divide the numerator by the denominator.

For example:

15/16 = .9375

Percentages

Expressing a number in percentage is just another way of writing a fraction or decimal. Think of percentages as parts of 100. In fractions, form the denominator of a percentage is always 100. To change a fraction to percent, multiply by 100.

Also remember whenever you multiply a whole number with a fraction you must put a 1 below the whole number so it looks like a fraction.

For example:

1/2 x 100 would be 1/2 x 100/1 = 100/2 = 50%

To change a percent to a fraction, multiply by 1/100%.

For example:

40% x 1/100% = 40%/100% = 4/10 = 2/5

The % / % cancel each other out.

Exponents

Indicates how many times a number is to be multiplied by itself.

For example:

2^3 = 2 x 2 x 2 = 8, where 3 is the exponent

4^2 = 4 x 4 = 16, where 2 is the exponent

You have already used exponents when you solve for squared (x^2)

Square Roots

The square root is the reverse operation of exponents. It indicates how many times a number is to be divided by itself. This is the symbol √.

For example:

$$\sqrt{9} = 3 \text{ because } 3 \times 3 = 9$$

$$\sqrt{4} = 2 \text{ because } 2 \times 2 = 4$$

A **square root of a number** *a* is a number *y* such that $y^2 = a$, in other words, a number *y* whose *square* (the result of multiplying the number by itself, or $y \times y$) is *a*.

For example, 4 and −4 are square roots of 16 because $4^2 = (-4)^2 = 16$.

Every non-negative real number *a* has a unique non-negative square root, called the *principal square root*, which is denoted by $\sqrt{a}$, where √ is called the *radical sign* or *radix*. For example, the principal square root of 9 is 3, denoted $\sqrt{9} = 3$, because $3^2 = 3 \times 3 = 9$ and 3 is non-negative. The term whose root is being considered is known as the *radicand*. The radicand is the number or expression underneath the radical sign, in this example 9.

Every positive number *a* has two square roots: $\sqrt{a}$, which is positive, and $-\sqrt{a}$, which is negative. Together, these two roots are denoted $\pm\sqrt{a}$.

Although the principal square root of a positive number is only one of its two square roots, the designation "*the* square root" is often used to refer to the *principal* square root. For positive *a*, the principal square root can also be written in exponent notation, as $a^{1/2}$.

Decimal Subtraction Exercise *Answers are provided.*

1a. 8.207 − 4.5	1b. 60.5 − 3.318	1c. 49.2 − 23.22
2a. 65.58 − 5.59	2b. 58.6 − 2.16 43	2c. 51.7 − 32.35 1
3a. 83.45 − 67.37	3b. 75.8 − 13.6	3c. 37.35 − 31.8
4a. 61.72 − 3.221	4b. 82.82 − 73.74	4c. 65.5 − 61.4
5a. 85.935 − 6.431	5b. 91.66 − 53.11	5c. 79.8 − 46.43

Answers 1a. 3.707, 2a. 59.99, 3a. 1608, 4a. 58.499, 5a. 79.504--- 1b. 57.182, 2b. 34.437, 3b. 62.2, 4b. 9.08, 5b. 38.55 -–1c. 25.98, 2c. 19.349, 3c. 5.55, 4c. 4.1, 5c. 33.37

Fractions/Decimals Practice Exercise, **Answers are provided**

Remember to practice writing the problem out like the previous examples. Writing it out will help you when we begin solving word problems that relate to our industry.

A. 3/8 + 1/8 =

B. 1/2 + 3/8 =

C. 2/3 + 1/5 =

D. 3/8 – 1/8 =

E. 1/2 – 3/8 =

F. 2/3 – 1/5 =

G. 3/8 x 1/8 =

H. 1/2 x 3/8 =

I. 2/3 x 1/5 =

J. 3/8 / 1/8 =

K. 1/2 / 3/8 =

L. 2/3 / 1/5 =

M. . 3/8 =

N. 1/8 =

O. 1/2 =

P. 1/5 =

Q. 2^2 =

R. 3^3 =

S. 5^4 =

T. D^2 =

U. $\sqrt{9}$ =

V. $\sqrt{D^2}$ =

Answers

A. 4/8 = 1/2
B. 7/8
C. 13/15
D. 1/4
E. 1/8
F. 7/15
G. 1/16
H. 3/16
I. 2/15
J. 3
K. 1 1/3
L. 3 1/3
M. 0.375
N. 0.125
O. 0.5
P. 0.2
Q. 4
R. 27
S. 625
T. D x D
U. 3
V. D

Units and Water Conversion Factors Review

We use various units in many different applications, especially in water or wastewater treatment. These are easy to memorize. The key to understanding units is knowing how they are used. Remember the saying “do not mix apples and oranges”.

Let’s look at time.

Seconds, Minutes, Hours and Days, are common measurements of time. They are all different meanings and yet they relate to one another. Let’s say we wanted to know how many minutes are in a day. We could set this up as a fraction:

$$\frac{60\ \text{min}}{1\ \cancel{\text{hr}}} \times \frac{24\ \cancel{\text{hr}}}{1\ \text{day}} = 1440\ \text{min/day}$$

When we set up the equation as above, the unit we are asking for will always follows the equal sign.

Remember cross cancellation, this will insure that the problem is set up properly. Understanding the hierarchy of the unit will indicate whether to multiply, getting a smaller unit to larger unit, or to divide, getting a larger unit to a smaller unit, for example let’s convert 45 gallons/min to gallons/day:

$$\frac{45\ \text{gal}}{1\ \cancel{\text{min}}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{hr}}} \times \frac{24\ \cancel{\text{hr}}}{1\ \text{day}} = \frac{64{,}800\ \text{gal}}{1\ \text{day}}$$

Let’s go the opposite direction and convert 64,800 gal/day to gal/min:

$$\frac{64{,}800\ \text{gal}}{1\ \cancel{\text{day}}} \times \frac{1\ \cancel{\text{day}}}{24\ \cancel{\text{hr}}} \times \frac{1\ \cancel{\text{hr}}}{60\ \text{min}} = \frac{45\ \text{gal}}{1\ \text{min}}$$

Water Pressure

Water pressure is measured in terms of pounds per square inch (psi) and feet of head (height of a water column in feet). A column of water 2.31 feet high creates a pressure of 1 psi. The water pressure at the bottom of a storage tank can be used to determine the water level in the tank. Centrifugal pumps are rated in feet of Total Dynamic Head (TDH) but system pressures are measured in psi. All water system operators must be able to convert from one pressure unit to the other.

If the pressure (psi) is known, The height of the water column can be determined by multiplying the psi by 2.31.

$$\text{psi} \times 2.31 = \text{Feet of Head}$$

Example:
1. A pressure gauge at the bottom of a storage tank reads 30 psi. What is the water level in the tank?

Convert psi to feet of head

30 psi x 2.31 = **69.3 feet of water above the gauge**

If the height of a column of water is known, the pressure it exerts can be determined by dividing the feet of head by 2.31.

$$\frac{\text{Feet of Head}}{2.31} = \text{psi}$$

Example:
2. The reservoir level is 115 feet above the pump discharge. What is the discharge pressure on the pump?

Convert feet of head to psi.

$$\frac{115 \text{ feet}}{2.31} = \mathbf{49.8\ psi}$$

Some units may seem unconvertible, for instance converting gallons to cubic feet, conversion factors allow us to do this. Below are some common ones used in the water and wastewater industry:

1 foot = 12 inches	1 minute = 60 seconds	cfs = cubic feet per second
1 inch = 2.54 centimeters	1 hour = 60 minutes	gpm = gallons per minute
1 gallon = 8 pints	1 day = 86,400 seconds	gpd = gallon per day
1 gallon = 8.34 pounds	1 day = 1,440 minutes	MGD = million gallons per day
1 gallon = 3.785 liters	1 day = 24 hours	mg/L = milligrams per liter
1 liter = 1,000 milliliters	1 % = 10,000 ppm	ppm = parts per million
1 cubic foot = 7.48 gallons	1 mg/L = 1 ppm	psi = pounds per square inch
1 cfs = 448 gpm	1 cubic foot = 62.38 pounds	fps = feet per second
1 gpm = 1,440 gpd	1 cubic yard = 27 cubic feet	cu ft = ft^3 = cubic feet
1 MGD = 1.55 cfs	1 gallon = 8 pints	sq ft = ft^2 = square feet
1 psi = 2.31 feet	1 MGD = 694.4 gpm	gpg = grains per gallon
1 foot = 0.433 psi	1 grain per gallon = 17.12 mg/L	π pi (pie) = 3.4

Conversion Exercise ***Answers are provided***

Let's give it a try, remember to practice writing the problem out like the previous examples. This will help you when we begin solving problems that relate to our industry.

Making a whole number look like a "F"raction, it's magic……

$$\frac{10}{1}$$

A. 87 seconds to minutes:

Hint: $\frac{87\text{seconds}}{1} \quad \frac{1\text{ minute}}{60\text{ seconds}}$

B. 1045 seconds to minutes:

C. 24 minutes to seconds:

D. 15 minutes to seconds:

E. 109 minutes to hours

F. 44 minutes to hours

G. 2.8 hours to minutes

H. 0.5 hours to minutes

I. 13 hours to days

J. 45 hours to days

K. 0.5 days to hours

L. 3 days to hours

M. 2 days to min

N. 452 min to days

O. 250 gpm to MGD

P. 600 gpm to MGD

Q. 120 gpm to MGD

R. 0.25 MGD to gpm

S. 1.3 MGD to gpm

T. 0.12 MGD to gpm

Convert the following:

U. 1500 cuft to gal

V. 5 cuft to gal

W. 500 cuft to gal

X. 100 gal to cuft

Y. 2500 gal to cuft

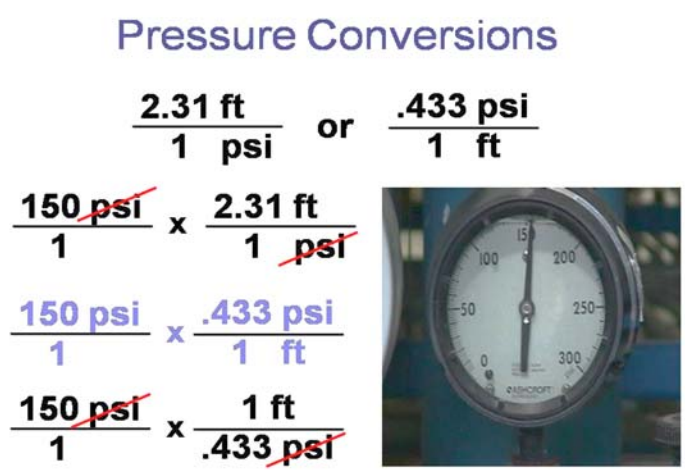
Z. 45 gal to cuft

Z1. 2.5 gal to lbs

Z2. 20 gal to lbs

Z3. 110 gal to lbs

Z4. 24 lbs to gal



Z5. 53 lbs to gal

Z6. 150 lbs to gal

Z7. 20 psi to ft

Z8. 100 psi to ft

Z9. 75 psi to ft

Z10. 100 ft to psi

Z11. 50 ft to psi

Z12. 500 ft to psi

Z13. 90 cu.ft. to lbs

Z14. 150 lbs to cu.ft.

Answers

A. 1.5 min
B. 17.4 min
C. 1440 sec
D. 900 sec
E. 1.8 hr
F. 0.7 hr
G. 168 min
H. 30 min
I. 0.5 day
J. 1.9 day
K. 12 hr
L. 72 hr
M. 2880 min
N. 0.3 day
O. 0.4 MGD
P. 0.9 MGD
Q. 0.2 MGD
R. 174 gpm
S. 903 gpm
T. 83 gpm
U. 11,220 gal
V. 37 gal
W. 3,740 gal
X. 13 cu.ft.
Y. 334 cu.ft.
Z. 6 cu.ft.
Z1. 21 lbs
Z2. 167 lbs
Z3. 917 lbs
Z4. 3 gal
Z5. 6 gal
Z6. 18 gal
Z7. 46 ft
Z8. 231 ft
Z9. 173 ft
Z10. 43 psi
Z11. 22 psi
Z12. 216 psi
Z13. 5614 lbs
Z14. 2 cu.ft.

Temperature Conversion Exercise

In water, there are two commonly measurement or scales for temperature, Fahrenheit (°F) and Celsius (°C) (centigrade).

Formulas used to solve for Temperature:

Fahrenheit (°F) = (1.8 x °C) + 32
Celsius (°C) = 0.56 x (°F – 32)

Let's give it a try, remember to practice writing the problem out like the previous examples. This will help you when we begin solving problems that relate to our industry.

Convert the following temperatures from Fahrenheit to Celsius.

1. 32°F

2. 70°F

3. 50°F

4. 85°F

5. 43.7°F

Convert the following temperatures from Celsius to Fahrenheit.

6. 32°C

7. 0°C

8. 10°C

9. 17°C

10. 23.4°C

Temperature Answers

1. 0
2. 21
3. 10
4. 30
5. 6.6
6. 89.6
7. 32
8. 50
9. 62.6
10. 74.1

Understanding and Solving Water Related Word Problems

1. Read the problem and use scratch paper:

    a. Underline the given information.

    b. Circle what is being asked for.

    c. Draw a picture or diagram and label with the given information.

2. Stop and think about what is being asked for:

    a. Look at the units; many times the units of the item being asked for will tell you how to do the problem.

    b. Do not go on until you understand what is being asked and you know how to proceed.

3. Select the proper formula:

    b. Treat the formula like a recipe. The word problem would be the ingredients needed. If the recipe does not match the ingredients, most likely it's the incorrect formula or you have not converted apples to apples.

    a. Write down the formula and then start writing down the various information given to you. If you do not have enough information to fill in all but one unit in the formula, you probably have the wrong formula for the problem.

4. Solve the formula.

5. Ask if the answer is reasonable:

    a. If it is not, you should go back and check your work or possibly you are not using the correct formula.

    b. Visually compare what is on paper with what is out in the field.

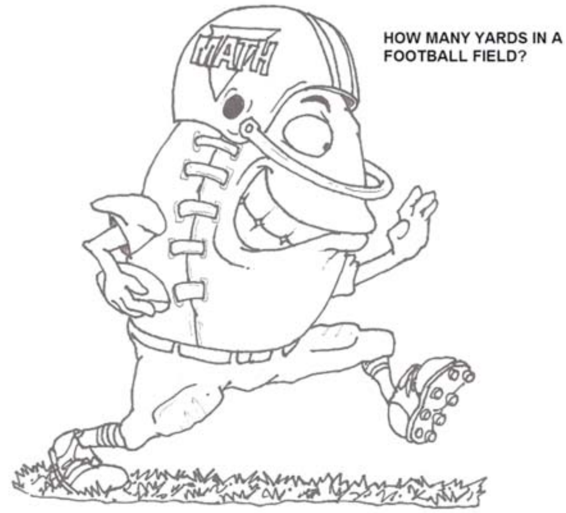
Linear Measurement Review

Linear measurements determine the length or distance along a line or curve, and are generally expressed in English units (inches, feet, yards, and miles) or metric units (centimeters, meters, and kilometers). We will cover the metric system, see table of contents.

How many yards in a football field?

How many feet in a football field?

How many cubic feet in a football field?



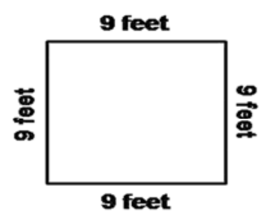
Perimeter

These measurements of distance are used to determine lengths, perimeters of shapes, diameters of circles, and circumferences of circles. Perimeters of shapes that are made up of straight lines are determined by adding the length of each side. It can be found using the formula:

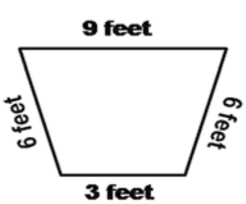
Perimeter = $\text{length}_1 + \text{length}_2 + \text{length}_3$ etc…

Perimeter calculations can be used to determine how many linear feet of pipe will be necessary for a specific design or how much wire will be needed to fence off an area.

6 ft + 6 ft + 6 ft = 18 ft



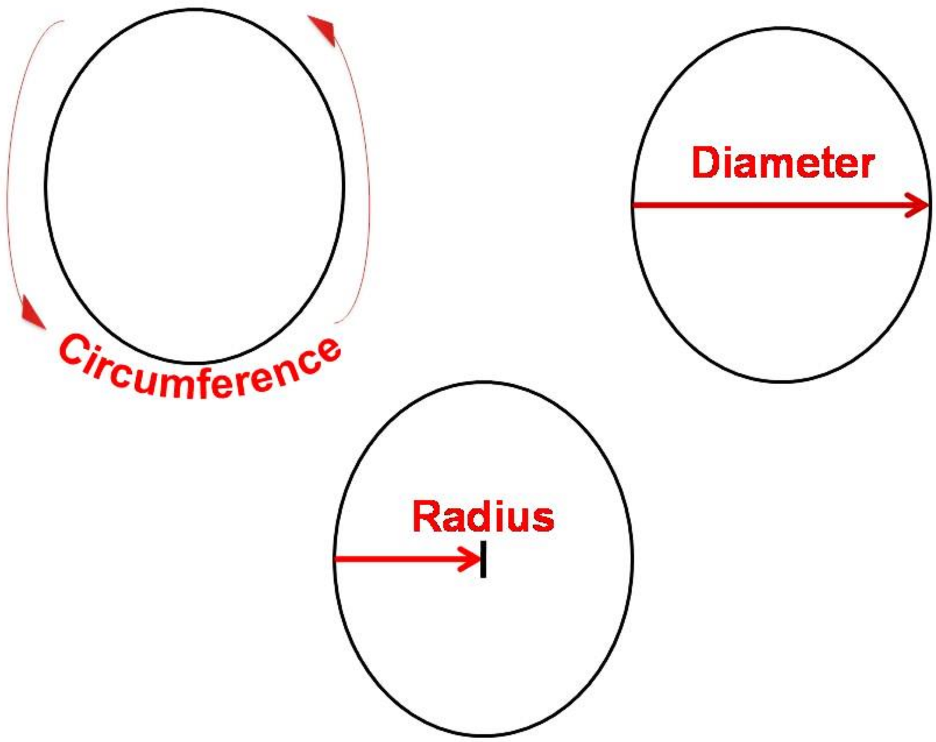
9 ft + 9 ft + 9 ft + 9 ft = 36 ft



9 ft + 6 ft + 3 ft + 6 ft = 24 ft

Circle and Circumference Review

Linear measurements are also used to determine the distance around, half way and across a circle. The terms used are circumference, radius and diameter. The diagram below shows how those terms apply to a circle:



We use the linear measurements as followed:

The **circumference** of a circle is the distance around the circle and is always equal to 3.14 times the length of the diameter. The special relationship between the diameter and circumference generates a constant number named pi (pronounced pie) and is designated by the Greek symbol (π), which = 3.14. If you know the diameter of a circle you can always calculate the circumference using the formula:

C = π x D where: C = Circumference, D = Diameter and π = 3.14

The **diameter** of a circle is the length of a straight line that crosses the center of the circle from one edge of the circle to another. It is twice the length of the radius. It can be determined by the formula:

D = 2r where: D = Diameter and r = radius

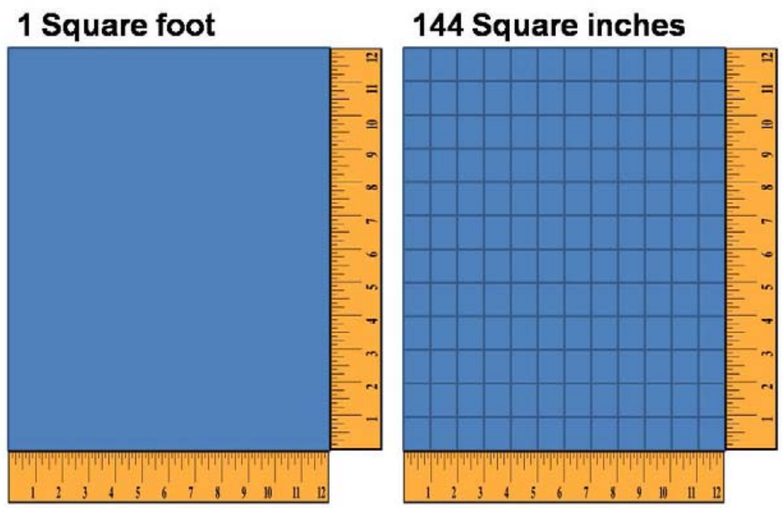
The **radius** of a circle is the distance from the center of the circle to the edge of the circle. It can be determined by the formula:

r = D divided by 2 where: r = radius and D = Diameter

Area Review

The term for an area unit measurement is normally in inches, feet and yards. The area measurement of a flat surface is the number of square units it contains. This is most helpful when we are tiling a floor and we need to know the total surface area of a room. We also refer to this measurement as square units. Area is equal to the length times the width. The diagram below shows that a 12 inch ruler is equal to one foot.

Using the formula for the **Area of a Rectangle: A = L x W** we can take 1 ft x 1 ft which equals 1 square foot or we can use inches which would be 12 inches x 12 inches equals 144 square feet.



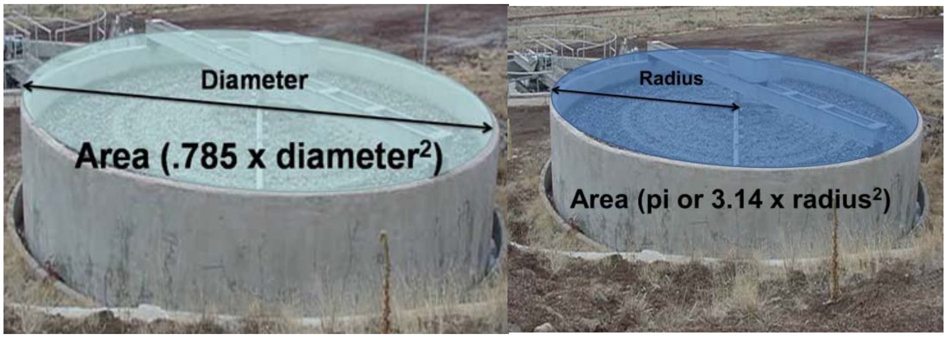
Area of a Circle
The area of a circle is found by squaring the diameter. By doing this operation the units will become squared and at that point the units are right for finding area. When you work an area problem you multiply the square of the diameter times 0.785. The formula for the area of a circle can be written as:

$$\textbf{Circle Area} = 0.785 \times D^2$$

In case you didn't know the number 0.785 is when you take pi (3.14) and divide it by 4 (4 quadrants of a circle).

You can also use the formula:

$$\textbf{Circle Area} = \text{pi } (3.14) \times r^2$$



Important Reminder

Don't be caught making the mistake of mixing inches and feet. For example how many **sq. inches** are in an area 5 inches x 12 feet?

Would we calculate it like this, 5 x 12 = 60 **or** 5 inches x 144 inches (the number of inches in 12 ft) = 720 **sq. inches**.

Let's give it a try, remember to practice writing the problem out like the previous examples. This will help you when we begin solving problems that relate to our industry.
Answers are provided

A. What is the area of a filter that is 8 ft by 12 ft?

B. What is the area of a clearwell that has a width of 25 ft and a length of 80 ft?

C. What is the area of the tank that is 10 ft long and 10 ft wide?

D. A tank has a diameter of 100 ft. What is the area?

E. What is the area of a clarifier with a diameter of 30 feet?

F. What is the area of a tank with a radius of 20 ft?

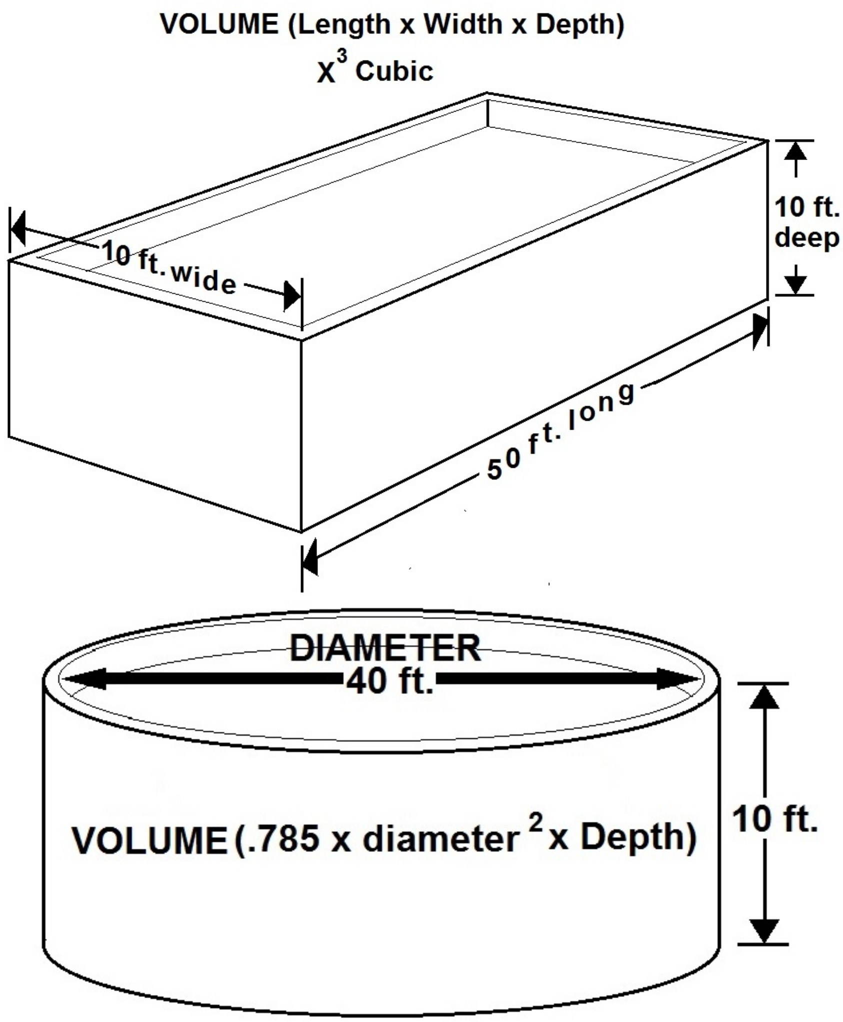
G. What is the circumference of a circle if the diameter is 20 ft?

H. What is the circumference of a circle if the radius is 15 ft?

I. What is area of a clarifier that is 15 ft across?

J. What is the area of a pipe in feet that has a 12 inch diameter?

Before we continue to solve more problems let's take a look at cubic feet or x^3. Cubic gives us the volume of a shape. It's the walls and floor in your house. For our industry it's clarifiers, reservoirs, tanks and pipes.



K. A tank is 10 ft long, 10 ft wide, with a depth of 5 ft. What is the volume of the tank?

L. What is the volume of a sedimentation basin that is 12 ft long, 6 ft wide and 10 ft deep?

Major "Need to Know"

$$\frac{7.48 \text{ gallons}}{1 \text{ cubic foot}}$$

This is how we"
Fill It!

After you build your tank, you'll need to fill it! To put water in our tank we multiply the conversion factors, to drain it we divide the conversion factors and you'll have the cubic measurements. Placing water in the tank, the numbers will increase, while removing water, the number decreases.

M. What is the capacity of a tank in gallons with the following dimensions, 12 ft by 10 ft by 8 ft?

N. A tank is 25 ft wide, 75 feet long and has a water depth of 10 ft. How many gallons of water are in the tank?

O. A clarifier has a diameter of 50 ft. If the depth of the water is 15 ft, what is the volume?

P. What is the volume of a piece of pipe that is 2000 ft long and has a diameter of **18 inches**?

Q. What is the perimeter of a water plant with the following dimensions: 100 ft, 250 ft, 300 ft, 500 ft, and 220 ft?

R. Your system has just installed 2, 000 feet of **8"** line. How many gallons of water will it take to fill this line?

S. Your finished water storage tank is 35' in diameter and 65' high. With no water entering it the level dropped 4' in 5 hours. How many gallons of water were used in this period?

T. If a clarifier has a diameter of 68 feet, and a height of 86 feet, what is the surface area of the water within the clarifier?

Answers

A. 96 sq ft
B. 2,000 sq ft
C. 100 sq ft
D. 7,850 sq ft
E. 706.5 sq ft
F. 1,256 sq ft
G. 62.8 ft
H. 94.2 ft
I. 176.625 sq ft
J. .785 sq ft
K. 500 cu ft
L. 720 cu ft
M. 960 cu ft
N. 140,250 gal
O. 29,438 cu ft
P. 3,533 cu ft
Q. 1,370 ft
R. 5,272 gal
S. 28,772 gal
T. 3,630 sq ft

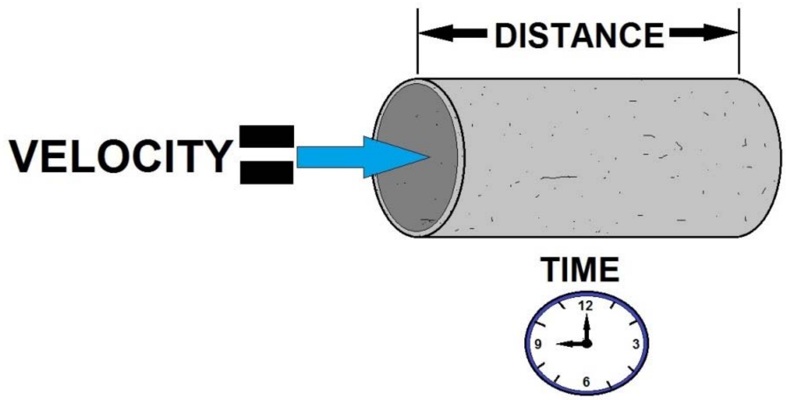
Velocity Review Section

Velocity is the measurement of speed at which something like water is moving. It is expressed by the distance traveled in a specific amount of time. Velocity can be expressed in any unit of distance per any unit of time for example, inch/second, feet/ minute, yard/day.

In the water and wastewater industry, velocity plays a key role when it is applied to friction loss or solids settling in a pipe. If you want to calculate the velocity you need to know the distance traveled and length of time that it took to cover the given distance.

The following formula is used to calculate the velocity.

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$



The following problem is an example of how the above formula is used:

A stick in a grit channel travels 26 feet in 32 seconds. What is the estimated velocity in the channel in feet/sec.?

Distance: 26 feet

Time: 32 seconds

Divide: 26 ft / 32 sec = .813 ft/sec

Sometimes the equation will give the units in unlike terms, for example:

A stick placed in a grit channel flows 36 feet in 3 minutes. What is the estimated velocity in the channel in feet/sec.?

Notice that the problem gave you minutes and they want the answer to be in seconds?

This is when you need to convert minutes to seconds before you plug your numbers into the formula. This is how you would do it:

$\underline{3\text{ min}} \times \underline{60\text{ sec}} = \underline{180\text{ sec}}$

The next step would be to plug the numbers into the formula:

Distance: 36 feet

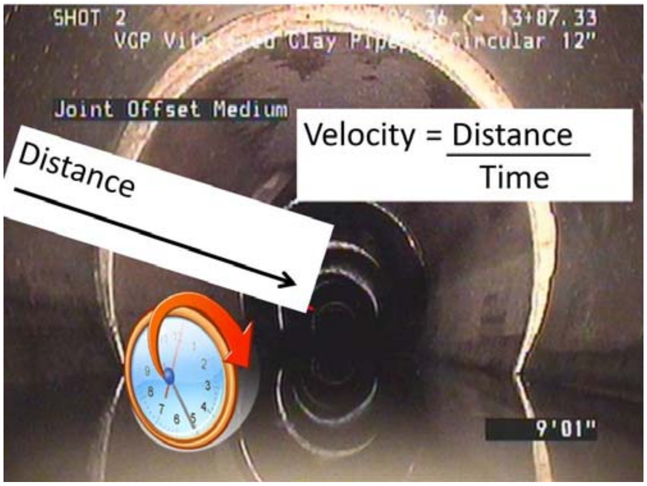
Time: 180 sec

Divide: 36 ft / 180 sec = .2 ft/sec

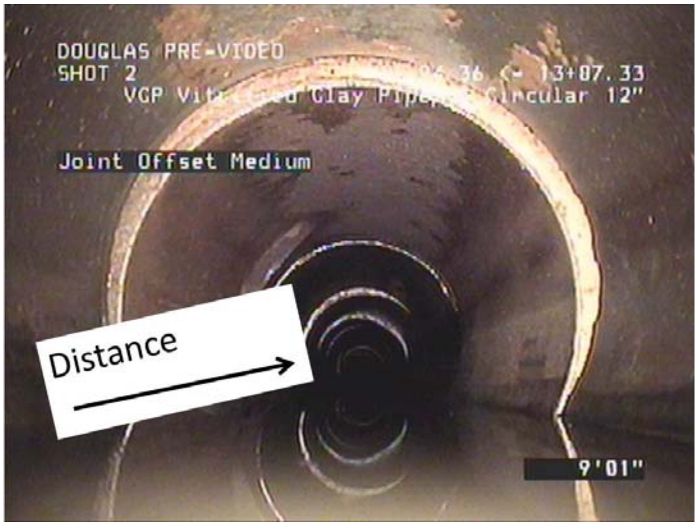
In a sewer system, velocity is recommended to be 2 ft/sec so that the solids will not settle out and cause backups. Collection operators often use dye test to determine how quickly the flow is running.

Flow Review

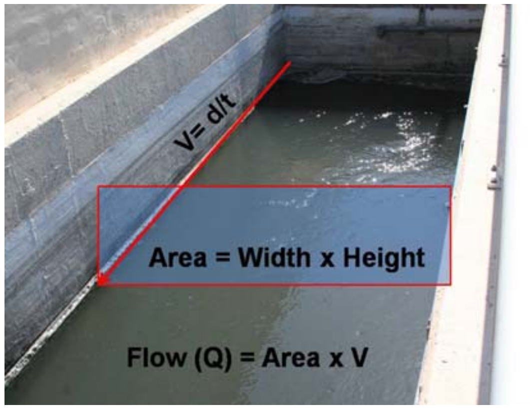
Velocity is measured using the linear distance and time as shown in the illustration below.



Flow is a function of the velocity of water at a given point multiplied by the cross sectional area of the pipe or channel. The outcome is a volume measurement in time. In the water and wastewater industry, we use the terms cfs (cubic feet per second), cfm (cubic feet per minute), or cfd (cubic feet per day).

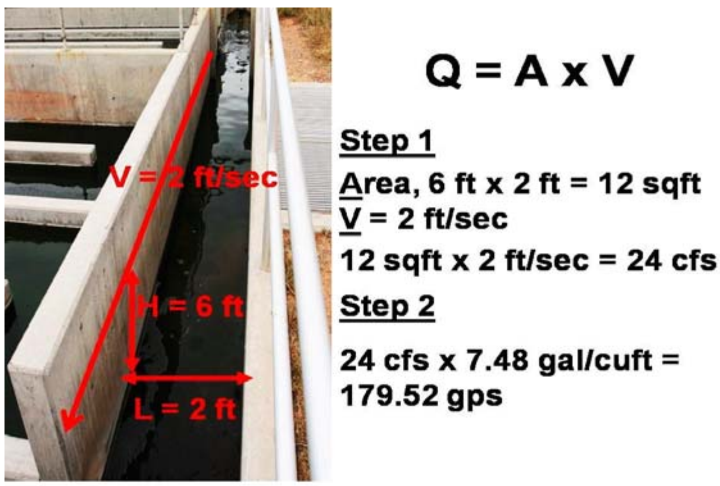


Water is introduced in the formula by multiplying the "Q" conversion factor 7.48 gal/cu.ft. The terms gps (gallons per second), gpm (gallons per minute), or gpd (gallons per day).
The illustration below shows the formula for a channel.



Water and wastewater facilities express the flow to a plant in the expression MGD, (million gallons per day). Let's look at a few examples of flow problems that convert gps to MGD.

Example 1
Let's calculate the flow in gallons per second by using the formula in the illustration below along with the given measurements.



The answer represents gps.

How would you convert gallons per second to gallons per minute?

$$\frac{45\ \text{gal}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} \times \frac{24\ \text{hr}}{1\ \text{day}} = \frac{64{,}800\ \text{gal}}{1\ \text{day}}$$

Convert 179.52 gps to gpm and write the answer in the space provided below. Using the example above convert gpm to gpd.

Answer: **15,510,582 gal/day.**

Now convert 15,510,582 gal/day to MGD.

$$\frac{15{,}510{,}582 \ \text{gal}}{\text{day}} \times \frac{1 \ \text{MG}}{1{,}000{,}000 \ \text{gal}}$$

$$\frac{15{,}510{,}582 \ \text{gal}}{1{,}000{,}000 \ \text{gal}} = 15.510 \ \text{MGD}$$

Three significant numbers after the decimal place.

$$1 \ \text{MG} = \frac{1{,}000{,}000 \ \text{Gallons}}{24 \ \text{Hour Fill time}}$$

Significant Number Reminder

The **significant figures** of a number are those digits that carry meaning contributing to its precision.

Numbers are often rounded to avoid reporting insignificant figures. For example, it would create false precision to express a measurement as 12.34500 kg (which has seven significant figures) if the scales only measured to the nearest gram and gave a reading of 12.345 kg (which has five significant figures).

Numbers can also be rounded merely for simplicity rather than to indicate a given precision of measurement, for example to make them faster to pronounce for water treatment purposed or distribution delivery.

Sedimentation Tanks and Clarifiers Formulas

Detention Time, hr = $\frac{\text{(Tank Volume, cu ft) (7.48 gal/cu ft) (24 hrs/day)}}{\text{Flow, gal/day}}$

Surface Loading, GPD/sq ft = $\frac{\text{Flow, GPD}}{\text{Surface Area, sq ft}}$

Weir Overflow, GPD/ft = $\frac{\text{Flow, GPD}}{\text{Length of Weir, ft}}$

Solids Applied, lbs/day = (Flow, MGD) (Solids, mg/l) (8.34 lbs/gal)

Solids Loading, lbs/day/sq ft = $\frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$

Trickling Filters (TF) and Rotating Biological Contactors (RBC)

Hydraulic Loading, GPD/sq ft = $\frac{\text{Flow, GPD}}{\text{Surface Area, sq ft}}$

BOD_5 Applied (TF), lbs/day = (Flow, MGD) (BOD5, mg/l) (8.34 lbs/gal)

Organic Loading (TF), lbs BOD5/day/1000 cu ft = $\frac{\text{BOD5 Applied, lbs/day}}{\text{Volume of Media, 1000 cu ft}}$

Soluble BOD Applied (RBC), lbs/day = (Flow, MGD) (Soluble BOD5, mg/l) (8.34 lbs/gal)

Organics Loading (RBC) lbs BOD5/day/1,000 sq ft = $\frac{\text{Soluble BOD5 Applied, lbs/day}}{\text{Surface Area of Media, 1,000 sq ft}}$

Detention Time Verses Retention Time

The use of **detention time** in water treatment generally refers to the length of time it takes water or wastewater to fill a basin or clarifier. Detention time is also a measurement of the time that water spends in a sedimentation tank. This is also thought of as the average length of time water or a suspended particles remains in a tank.

Retention time is the amount of time a substance or bug stays in a basin. Retention time is used during the biological process in wastewater and is commonly called Solids Retention Time, SRT. Increased retention time creates a larger active area improving efficiency and reducing the Total Suspended Solids (TSS).

$$\text{The formula for Detention Time: } \frac{\text{Volume}}{\text{Flow}}$$

The key to solving any problem is to make sure that the math terms relate and that you understand them.

The formula uses volume, this indicates that you will need to build a vessel that is either circular, rectangular or it may have the shape of a cone. You'll need to convert the cubic measurement into gallons and then divide by flow which is typically presented in gallons per a certain time unit like in hours. Detention time can be in seconds, minutes, hours or days.

Detention has to do with flow and Retention has to do with time.

For example:

A rectangular basin 12 feet long and 9 feet wide and 6 feet deep. It treats a flow of 90,000 gallons per day. Determine the detention time in hours.

1. Determine tank volume in gallons.

Volume = (length)(width)(depth)

(12 ft)(9 ft)(6 ft)

Volume = 648 ft^3

2. To convert from cubic feet to gallons multiply by 7.48. The formula sheet shows that there are 7.48 gallons in 1 cubic foot.

648 ft^3 X 7.48 gal/ ft^3 = 4,847 gallons

3. Calculate the resulting detention time in hours using the formula stated above.

$$Detention\ time = \frac{4{,}847\ \text{gal}}{90{,}000\ \text{gal/day}} = 0.054\ \text{day}$$

$$0.054\ day\ x\ \frac{24\ hr}{1\ day} = 1.3\ \text{hours}$$

Detention time can be in seconds, minutes, hours or days. Just remember to convert. Make sure that the volume in gallons matches the flow units. For instance if the previous example gave you the flow as .090 MGD you would have converted it to 90,000 gallon to match the volume that is in gallons.

Let's give it a try, remember to practice writing the problem out like the previous examples. This will help you when we begin solving problems that relate to our industry.
Answers not provided

1. Find the detention time of a tank that measures 50 feet long, 30 feet wide and 10 feet deep with a flow to the tank of 1500 gpm?

2. The flow to a tank that is 50 ft long, 30 ft wide and 10 ft deep is 0.32 MGD. What is the detention time in hours?

3. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet when the inflow is 1000 gpm?

4. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet, when it starts full and is discharging 2500 gpm and has an inflow of 1500 gpm?

5. Find the detention time, in days, of a tank with a diameter of 100 ft and a water depth of 60 feet, when it starts 1/2 full and is discharging 2500 gpm and has an inflow of 1500 gpm?

6. A channel 3 ft wide has water flowing to a depth of 2.5 ft. If the velocity through the channel is 2 fps, what is the cfs flow rate through the channel?

7. The flow through a 6 inch diameter pipeline is moving at a velocity of 300 ft/sec. What is the cfs flow rate through the pipeline?

8. If a pipe has a 1-ft diameter, what is the velocity of the water if the pipe is carrying $2ft^3$/sec?

9. A sedimentation tank holds 80,000 gallons and the flow into the plant is 855 gpm. What is the detention time in minutes?

10. What is the detention time in a sedimentation basin 80 ft long, 20 ft wide and 10 ft high if the rate of flow is 5800 gal/min?

Chemical Feeder Setting Formulas

Chemical Dose, lbs/day = (Flow, MGD) (Dose, mg/lL (8.34 lbs/gal)

Chemical Feeder Setting, ml/min =

$$\frac{\text{(Flow, MGD) (Chemical Dose, mg/l) (3.875 l/gal) (1,000,000/M)}}{\text{(Liquid Chemical, mg/l) (24 hr/day) (60 min/hr)}}$$

Chemical Feeder Settling, gal/day = $\frac{\text{(Flow, MGD) (Chemical Dose, mg/l) (8.34 lbs/day)}}{\text{Liquid Chemical, lbs/gal}}$

Liquid Feed Pump Calibration Formulas

Chemical Feed, lbs/day =

$$\frac{\text{(Chemical Conc., mg/L) (Volume Pumped, mL) (60 min/hr) (24 hr/day)}}{\text{(Time Pumped, min) (1,000, mL/L) (1,000, mL/mg) (454 gm/lb)}}$$

Chemical Feed, GPM = $\frac{\text{Chemical Used, gal}}{\text{(Time, hr) (60 min/hr)}}$

Chemical Feed, GPM = $\frac{\text{(Chemical Feed Rate, mL/sec) (60 sec/min)}}{\text{3.875 mL/gal}}$

Chemical Solution, gal = $\frac{\text{(Chemical Solution, \%) (8.34 lbs/gal)}}{\text{100 \%}}$

Feed Pump, GPD = $\frac{\text{Chemical Feed, lbs/day}}{\text{Chemical Solution, lbs/gal}}$

Feeder Setting, % = $\frac{\text{(Desired Feed Pump, GPD) (100 \%)}}{\text{Maximum Feed Pump, GPD}}$

Chemical and Chlorine Dosing Review

The water operator needs to understand the importance of calculating the proper amount of chemical like chlorine or alum that we add to the water or wastewater. This unit may be expressed as either parts per million (ppm) or milligrams per liter (mg/L). They are considered to be equal. *1 ppm = 1 mg/L*

The above calculation helps determine the number of pounds of chemical or solids in water or wastewater. The flow is simply converted to million pounds of water. The loadings are calculated by multiplying the following; the flow expressed in MGD, the weight of one gallon of water (8.34 lbs/gal), and the amount of chemical being added in parts per million or milligrams per liter. When using the chemical dosing formula, we assume the concentration of the chemical is 100%. Very rarely is a chemical 100 percent pure except for Chlorine gas. When chemicals are added, we typically use a simple measuring device called a rotometer as shown below.

The photo above on the right is a chlorinator and on the left is a rotometer close-up shown with numbering representing pounds of chlorine fed.

Calculating Chemical Feed
Formula: Chemical Feed (lbs/day) = Dose (mg/L) x Flow (MGD) x (8.34 lbs/gal)

Example: How many pounds of chlorine must be added to 2 MGD if the dose is 1.5 mg/L?

Note: The flow is generally represented in millions or “Millionth”, this is very important in how it relates to mg/l or parts per million. If you had to treat 1 gallon of water using this chemical feed formula you would have to convert it to .000001 MG. To understand this in dollars, if you had 1 dollar, you can say you have .000001 million dollars.

Chemical Feed (lbs/day) = Dose (mg/L) x Flow (MGD) x (8.34 lbs/gal)
(1.5 ppm) x (2 MGD) x (8.34 lbs/gal)
= 25.02 lbs/day

There are many chemicals used in the operation of water and wastewater systems that contain a chemical combination or an active percentage. One example is calcium hypochlorite (HTH), which is commonly 65 percent available chlorine and sodium hypochlorite (bleach) which is 12.5 percent chlorine.

HTH is a solid form of chlorine while bleach is a liquid. When using bleach, we feed it in gallons per day and because it is not 100% so we need to make up the difference. The formula to feed gallons of chemical that is less than 100% is as followed:

Formula:

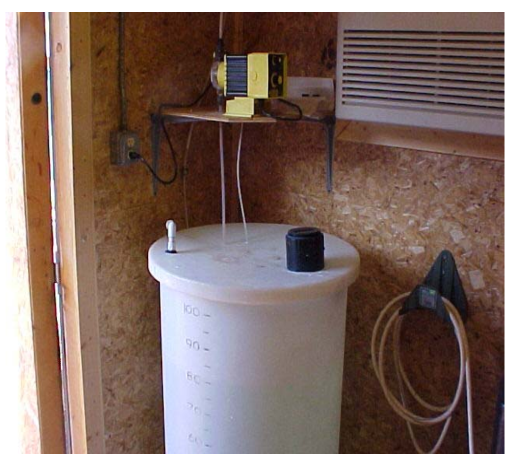
Chemical Feed (gallons/day) = Dose (mg/L) x Flow (MGD)
%purity (as a decimal)

Notice that 8.34 lbs/gal are not being used. The feed rate is in gallons, no need to convert it to pounds.

Example: How many gallons of 12.5 % bleach would be required if the dose is 30 ppm and the storage tank hold 25,000 gallons?

Chemical Feed (lbs/day) = Dose (mg/L) x Flow (MGD)
% purity (as a decimal)

= (30 ppm) x (.025 MGD)
= .75 gallons/day
= .75 gallons/day ÷ .125
= 6 gallons/day



Calculating Dose

To calculate dose, you must simply re-arrange the previous formula for calculating chemical feed. *See formula below.*

Formula: Dose (mg/L) = Chemical Feed (lbs/day) x Flow (MGD) X (8.34 lbs/gal)

Example: A 0.52 MGD system is feeding chlorine at a rate of 12 lbs/day. What will be the resulting chlorine dose?

$$\text{Dose (mg/L)} = \frac{\text{Chemical Feed (lbs/day)}}{\text{Flow (MGD) X (8.34 lbs/gal)}}$$

$$= \frac{12 \text{ lbs/day}}{(0.52 \text{ MGD})(8.34 \text{ lbs/day})}$$

$$= 2.76 \text{ mg/L}$$

Calculating Flow

To calculate flow, you also re-arrange the chemical feed formula. *See formula below.*

Formula: Flow (MGD) = Chemical Feed (lbs/day) X Dose (mg/L) X (8.34 lbs/gal)

Example: What would the calculated flow be with a feed rate of 15 pounds per day and a chlorine dose of 1.2 mg/L?

$$\text{Flow (MGD)} = \frac{\text{Chemical Feed (lbs/day)}}{\text{Dose (mg/L) X (8.34 lbs/gal)}}$$

$$= \frac{15 \text{ lbs/day}}{(1.2 \text{ mg/L})(8.34 \text{ lbs/day})}$$

$$= 1.5 \text{ MGD}$$

Chlorine Demand

The formula for chlorine dosage is equal to the chlorine demand plus the residual.

Formula: Dose (mg/L) = Demand (mg/L) + Residual (mg/L)

Example: What is the chlorine dose, if the chlorine demand is 4.8 mg/L and the chlorine residual
is 2 mg/L?

Dose (mg/L) = Demand (mg/L) + Residual (mg/L)

= 4.8 mg/L + 2 mg/L

= 6.8 mg/L

Example: What is the chlorine demand in milligrams per liter if the chlorine dose is 3.2 mg/L and the residual is 0.3 mg/L?

Demand (mg/L) = Dose (mg/L) – Residual (mg/L)

= 3.2 mg/L - 0.3 mg/L

= 2.9 mg/L

Example: What is the chlorine residual, if the chlorine demand is 1.8 mg/L and the chlorine dose is 10 mg/L?

Residual (mg/L) = Dose (mg/L) – Demand (mg/L)

= 10 mg/L – 1.8 mg/L

= 8.2 mg/L

Chemical Dosing Exercises, **Answers not provided**

1. Determine the chlorinator setting (lbs/day) needed to treat a flow of 3 MGD with a chlorine dose of 4 mg/L.

2. Determine the chlorinator setting (lbs/day) if a flow of 3.8 MGD is to be treated with a chlorine dose of 2.7 mg/L.

3. A jar test indicates that the best dry alum dose is 12 mg/L. If a flow is 3.5 MGD, what is the desired alum feed rate?

4. The chlorine feed rate at a plant is 175 lbs/day. If the flow is 2,450,000 gpd, what is the dosage in mg/L?

5. A total chlorine dosage of 12 mg/L is required to treat particular water. If a flow 1.2 MGD and the hypochlorite has 65% available chlorine how many lbs/day of hypochlorite will be required?

6. A flow of 800,000 gpd requires a chlorine dose of 9 mg/L. If chlorinated lime (34% available chlorine) is to be used, how many lbs/day of chlorinated lime will be required?

7. Determine the flow when 45 lbs of chlorine results in a chlorine dose of 1.7 mg/L.

8. A pipeline 10 inches in diameter and 900 ft long is to be treated with a chorine dose of 50 mg/L. How many lbs of chlorine will this require?

9. The flow meter reading at 8 am on Wednesday was 18,762,102 gal and at 8 am on Thursday was 19,414,522 gal. If the chlorinator setting is 15 lbs for this 24 hour period, what is the chlorine dosage in mg/L?

10. To disinfect an 8-inch diameter water main 400 feet long, an initial chlorine dose of 400 mg/L is expected to maintain a chlorine residual of over 300 mg/L during a three hour disinfection period. How many gallons of 5.25 percent sodium hypochlorite solution is needed?

Chemical Demand Exercises, **Answers not provided**

1. What is the chlorine demand in mg/L, if the chlorine dose is 3.2 mg/L and the chlorine residual is 0.3 mg/L?

2. What is the chlorine residual, if the chlorine demand is 1.8 mg/L and the chlorine dose is 10 mg/L?

3. What is the chlorine dose, if the chlorine demand is 4.8 mg/L and the chlorine residual is 2 mg/L?

4. The chlorine demand is 7 mg/L and the chlorine residual is 0.2 mg/L. What is the chlorine dose?

5. The chlorine dose is 5 mg/L and the chlorine demand is 2.7 mg/L. What is the chlorine residual?

6. The chlorine dose is 12 mg/L and the chlorine residual is 1.5 mg/L. What is the chlorine demand?

7. What is the chlorine demand in mg/L, if the chlorine dose is 5.2 mg/L and the chlorine residual is 0.3 mg/L?

8. If an operator feeds a chlorine dosage of 1.8 mg/L and the system has a chlorine demand of 1.3 mg/L, what would the final chlorine residual be?

9. What is the chlorine residual, if the chlorine demand is 2.3 mg/L and the chlorine dose is 3.4 mg/L?

10. What is the chlorine demand if the chlorine residual is 1.2 mg/L and 4.7 mg/L of chlorine has been added?

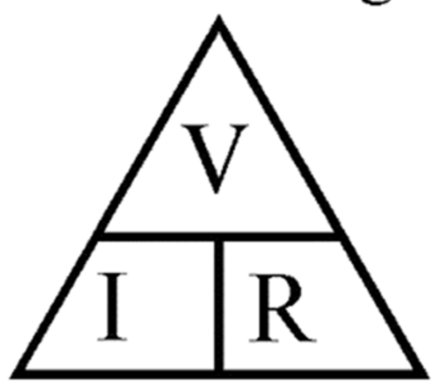
Electrical Math Review Section

Ohm found that in an electric circuit that the current through a conductor between two points is directly proportional to the potential difference across the two points. Introducing the constant of proportionality, the resistance, one arrives at the usual mathematical equation that describes this relationship:

$$I = \frac{V}{R},$$

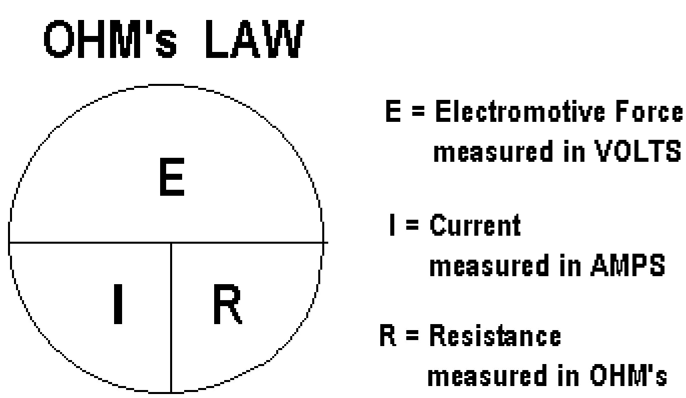
Where *I* is the current through the conductor in units of amperes, *V* is the potential difference measured *across* the conductor in units of volts, and *R* is the resistance of the conductor in units of ohms. More specifically, Ohm's law states that the *R* in this relation is constant, independent of the current.

Ohm's Triangle



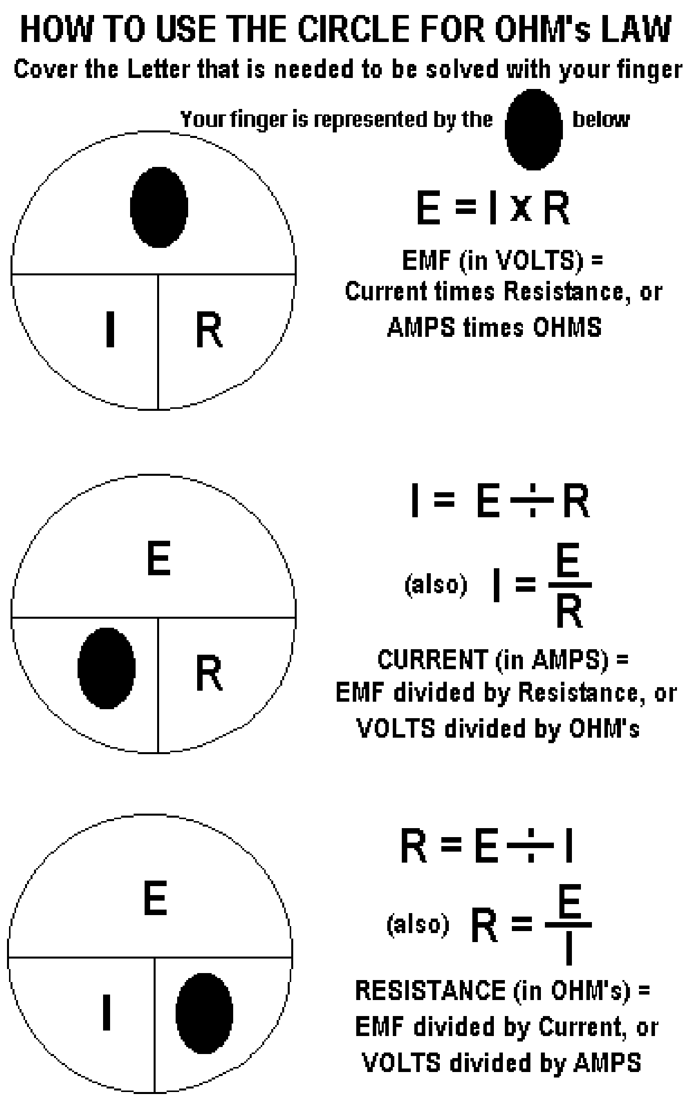
Cover the variable you want to find and perform the resulting calculation *(Multiplication/Division)* as indicated.

Or also expressed as



$E = I \times R \quad I = E \div R \quad R = E \div I$

HINT: The letters are placed on the circle in alphabetical order



V comes from "voltage" and ***E*** from "electromotive force". ***E*** means also **energy**, so ***V*** is chosen.

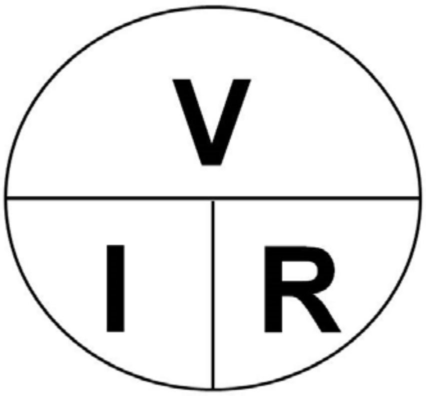
Energy = voltage × charge. $\boldsymbol{E} = \boldsymbol{V} \times \boldsymbol{Q}$. Some like better to stick to ***E*** instead to ***V***, so do it.

Voltage $\boldsymbol{V} = I \times R = P / I = \sqrt{(P \times R)}$ in volts V   Current $\boldsymbol{I} = V / R = P / V = \sqrt{(P / R)}$ in amperes A

Resistance $\boldsymbol{R} = V / I = P / I^2 = V^2 / P$ in ohms Ω   Power $\boldsymbol{P} = V \times I = \mathrm{R} \times I^2 = V^2 / R$ in watts W

Memory wheels provide an easy way to remember the relationship in Ohm's Law. If you cover the V (E is sometimes used for EMF, electrical motive force), the wheel tells you that "V" (voltage) is equal to "I" (current or amperage) multiplied by "R" (resistance).

By covering I or R you would divide by V, for example:



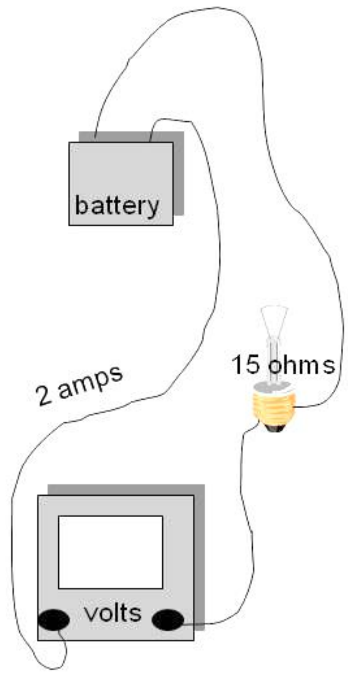
I = V ÷ R

R = V ÷ I

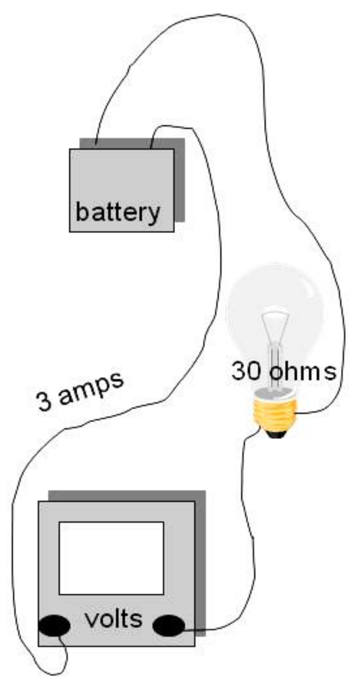
V = I x R

Solve the following problems using Ohm's Law. Some of the answers will have decimal points.

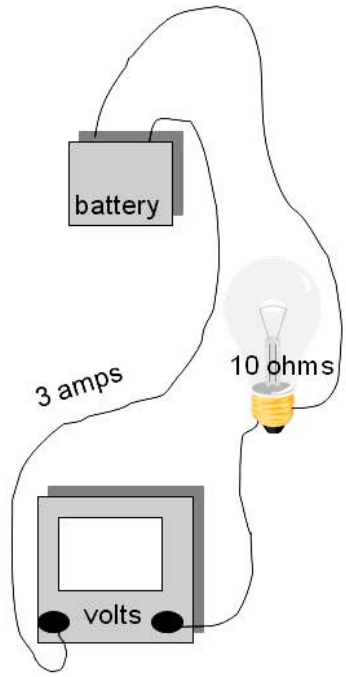
Voltage Practice Exercise



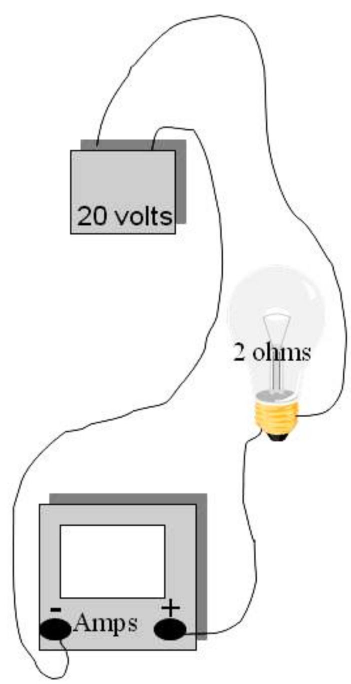
1. What is the voltage for the above? ____



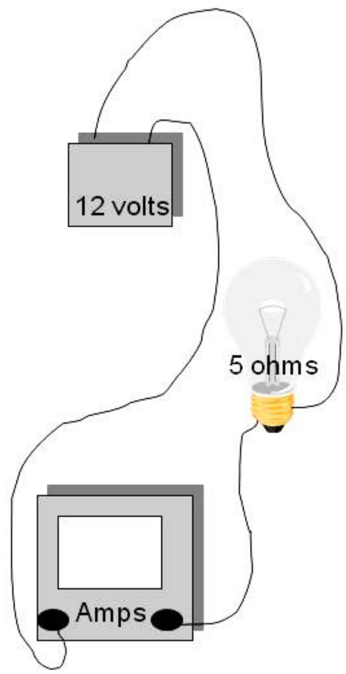
2. What is the voltage for the above? ____



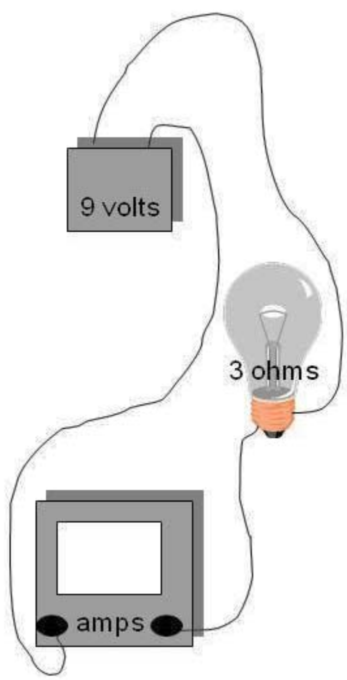
3. What is the voltage for the above? ____



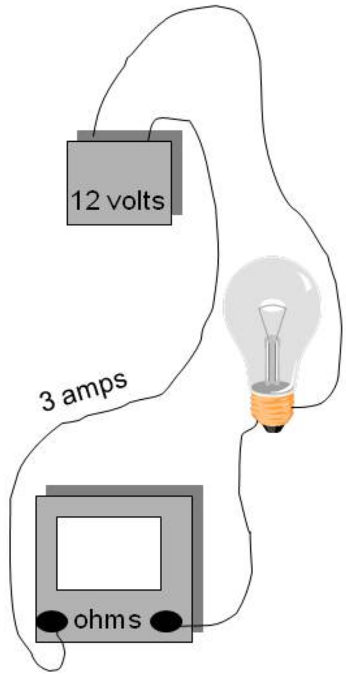
4. How much current will the load draw? ____



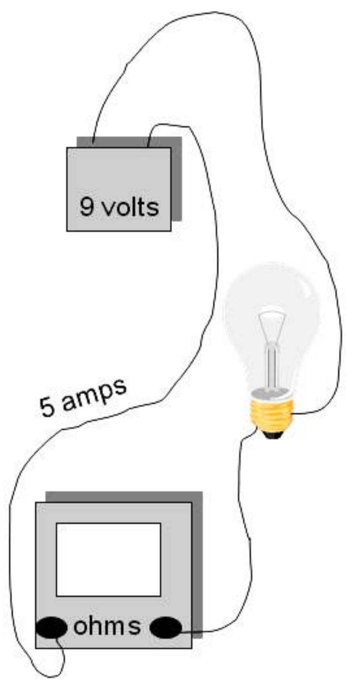
5. How much current will the load draw? ____



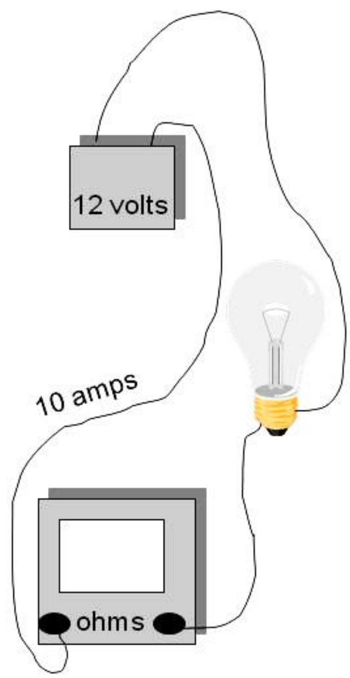
6. How much current will the load draw? ____



7. What is the resistance of this load? ____



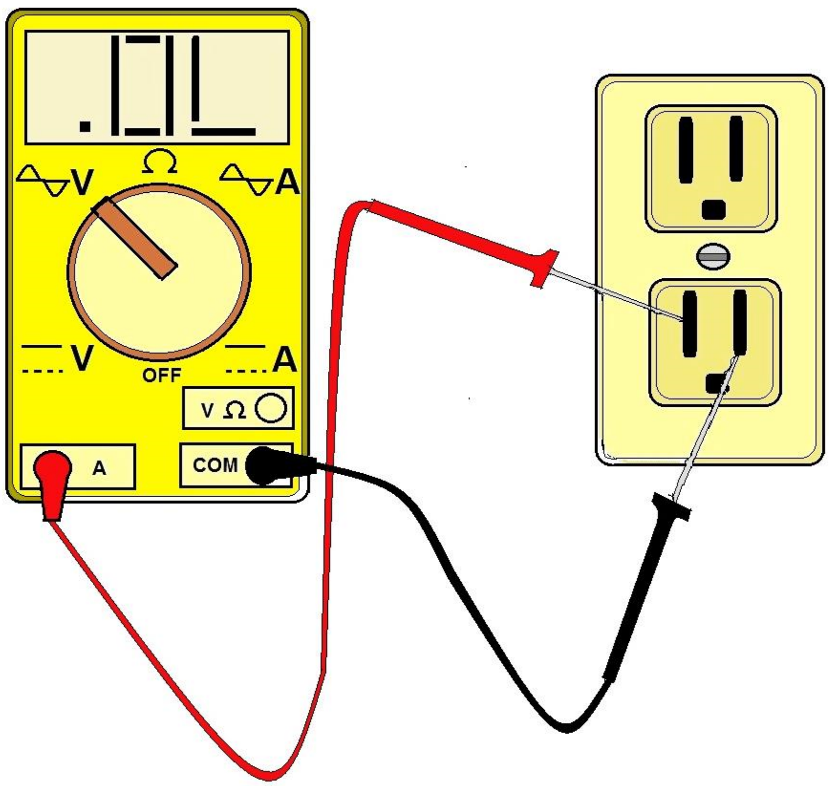
8. What is the resistance of this load? ____



9. What is the resistance of this load? ____

Answers for Practice Exercise 1-9

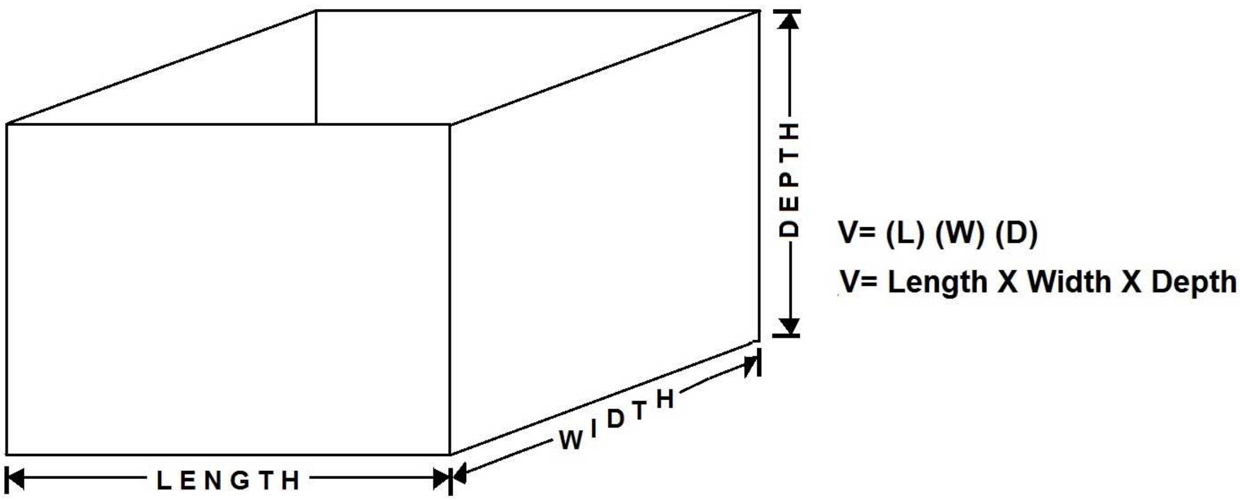
1. 2 **I** X 15 R = 30 V
2. 3 **I** x 30 R = 90 V
3. 3 **I** x 10 R = 30 V
4. 20 V ÷ 2 R = 10 **I** (amps)
5. 12 V ÷ 5 R = 2.4 **I** (amps)
6. 9 V ÷ 3 R = 3 I (amps)
7. 12 V ÷ 3 **I** = 4 R
8. 9 V ÷ 5 **I** = 1.8 R
9. 12 V ÷ 10 **I** = 1.2 R



SHORT CIRCUIT

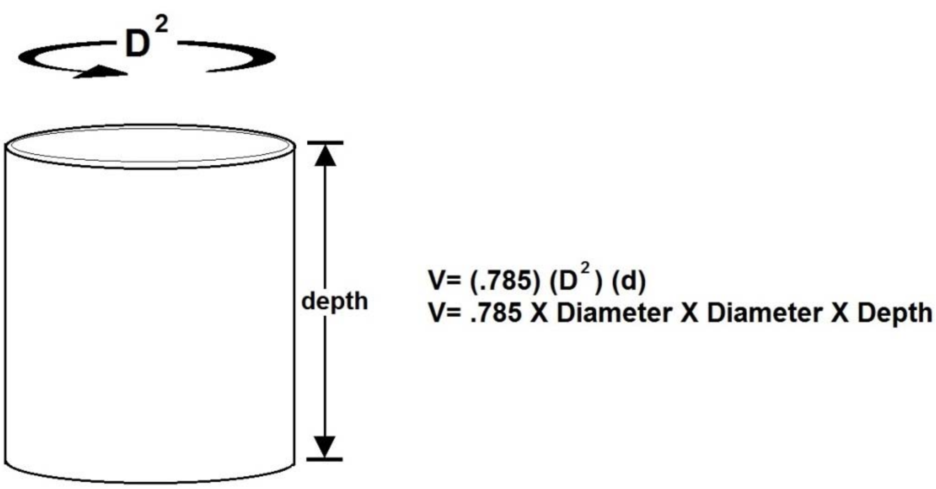
Operator Math Practice Section

Diagrams are provided to help you visualize or figure the solution.



CALCULATING THE VOLUME OF A CUBE

Cube Formula
V= (L) (W) (D)
Volume= Length X Width X Depth



CALCULATING THE VOLUME OF A CYLINDER

Cylinder Formula
V= (.785) (D^2) (d)

Math Conversion Factors

1 PSI = 2.31 Feet of Water
1 Foot of Water = .433 PSI
1.13 Feet of Water = 1 Inch of Mercury
454 Grams = 1 Pound
2.54 CM =Inch
1 Gallon of Water = 8.34 Pounds
1 mg/L = 1 PPM
17.1 mg/L = 1 Grain/Gallon
1% = 10,000 mg/L
694 Gallons per Minute = MGD
1.55 Cubic Feet per Second = 1 MGD
60 Seconds = 1 Minute
1440 Minutes = 1 Day
.746 kW = 1 Horsepower

LENGTH
12 Inches = 1 Foot
3 Feet = 1 Yard
5,280 Feet = 1 Mile

AREA
144 Square Inches = 1 Square Foot
43,560 Square Feet = 1 Acre

VOLUME
1000 Milliliters = 1 Liter
3.785 Liters = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Dimensions

SQUARE: Area (sq.ft.) = Length X Width
Volume (cu.ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft.) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. Ft.) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter ^{2} X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14)\ (\text{Diameter})^3}{(6)}$

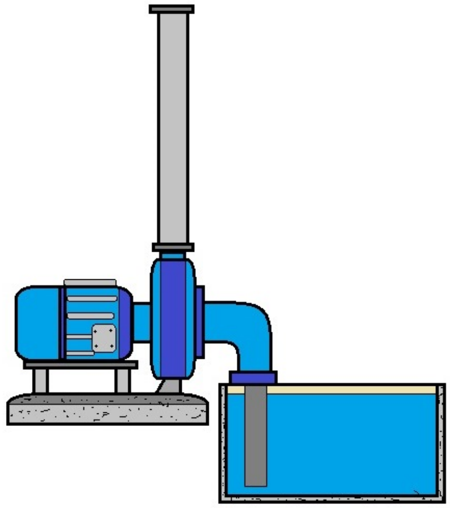
Circumference = 3.14 X Diameter

General Conversions
Flowrate

Multiply	**—>**	**to get**
to get	**<—**	**Divide**
cc/min	1	mL/min
cfm (ft^3/min)	28.31	L/min
cfm (ft^3/min)	1.699	m^3/hr
cfh (ft^3/hr)	472	mL/min
cfh (ft^3/hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m^3/hr
GPM	3.785	L/min
oz/min	29.57	mL/min

Water Pumping Math Section

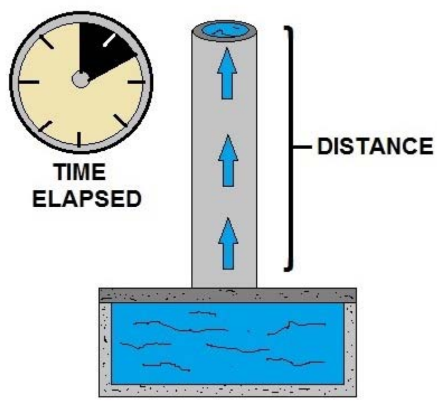
$$BHP = \frac{Q \times H}{3960 \times n} \times s.g.$$



BHP= Brake Horsepower
Q= Flow
H= Head
n= Efficiency
s.g.= Specific Gravity (always constant)

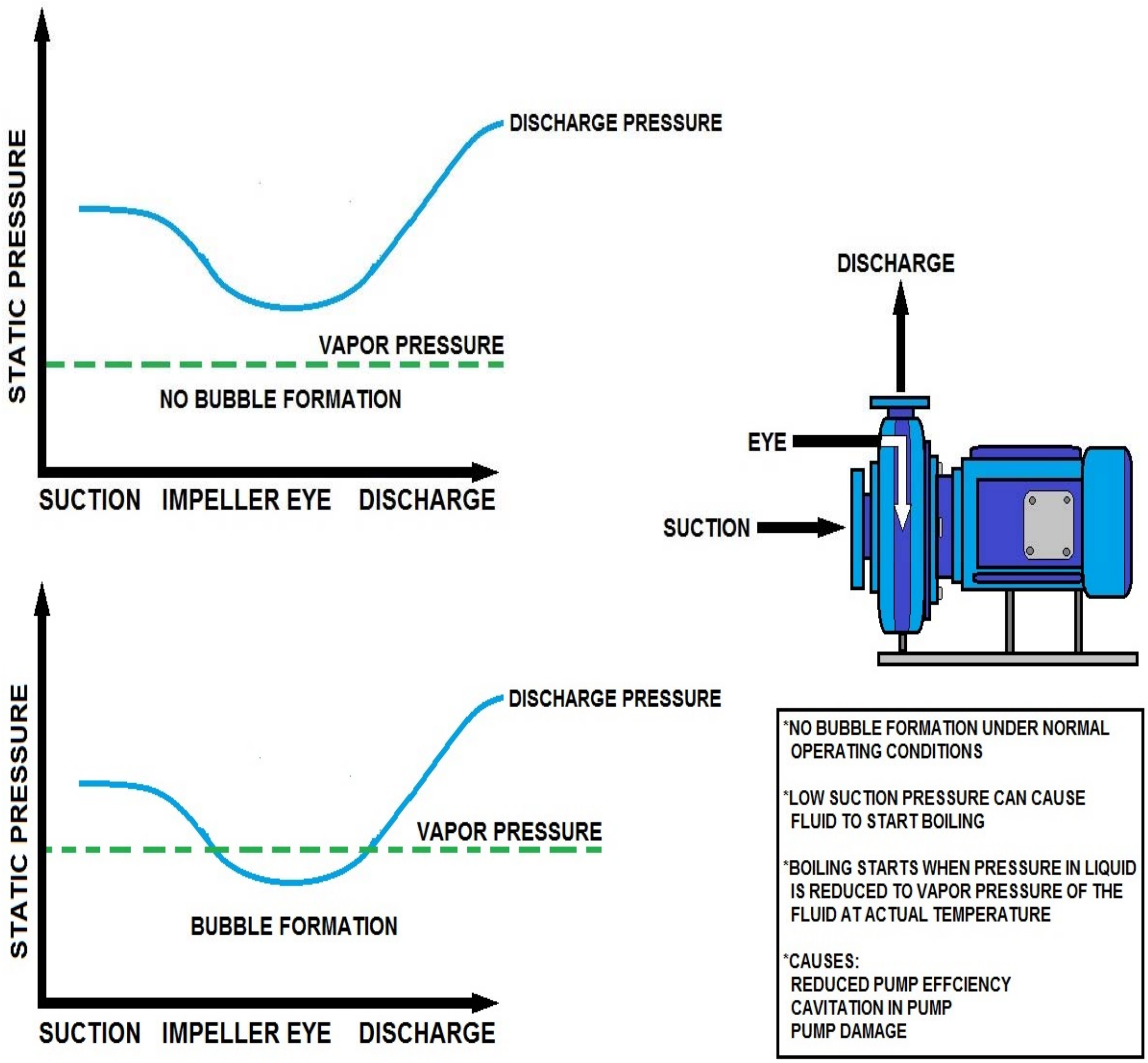
BRAKE HORSEPOWER
(The available power of a motor assesed by measuring the force needed to brake motor)

$$WHP = \frac{Q \times H}{3960}$$

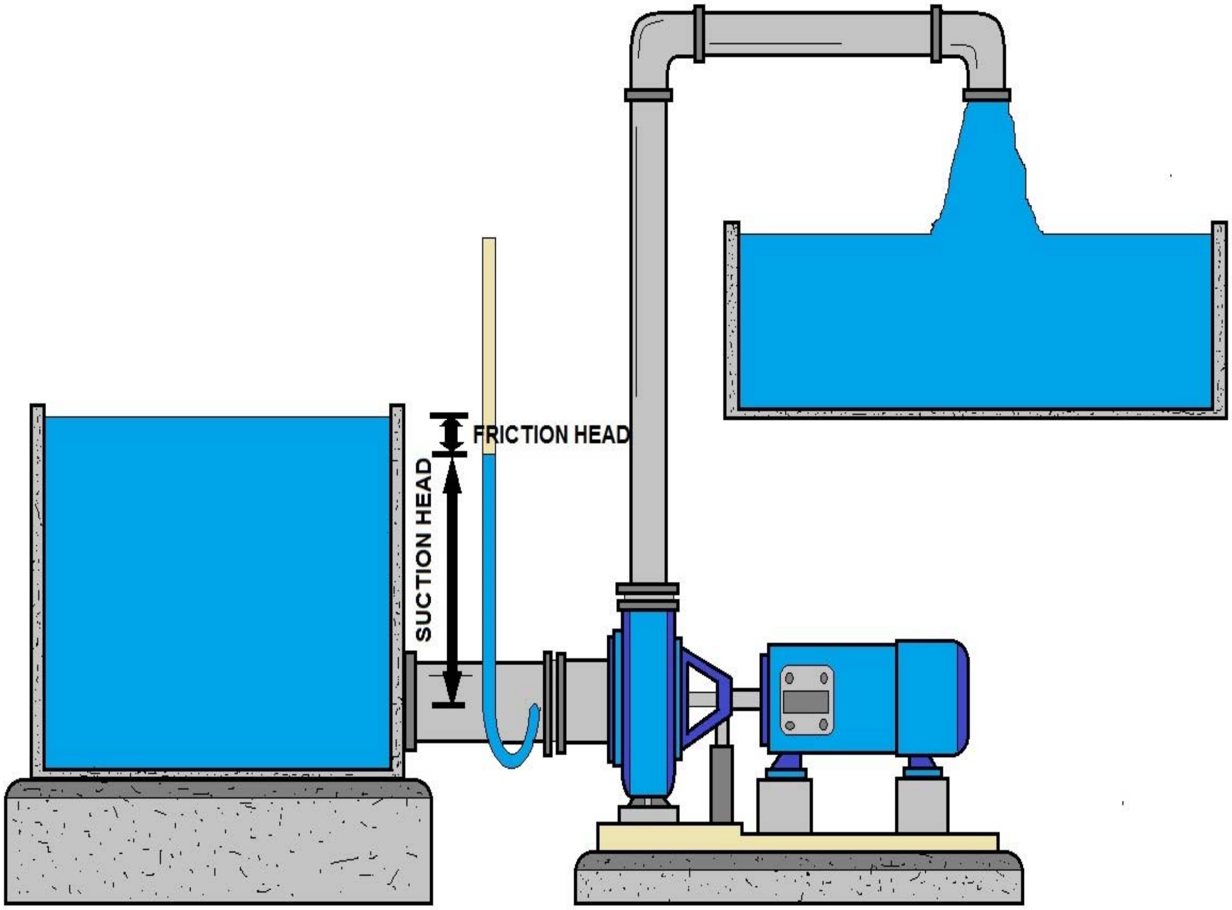


Q= FLUID FLOW RATE (gal/min)
H= TOTAL DYNAMIC HEAD (feet)
3960= FACTOR THAT CONVERTS HORSEPOWER INTO PUMPING TERMS

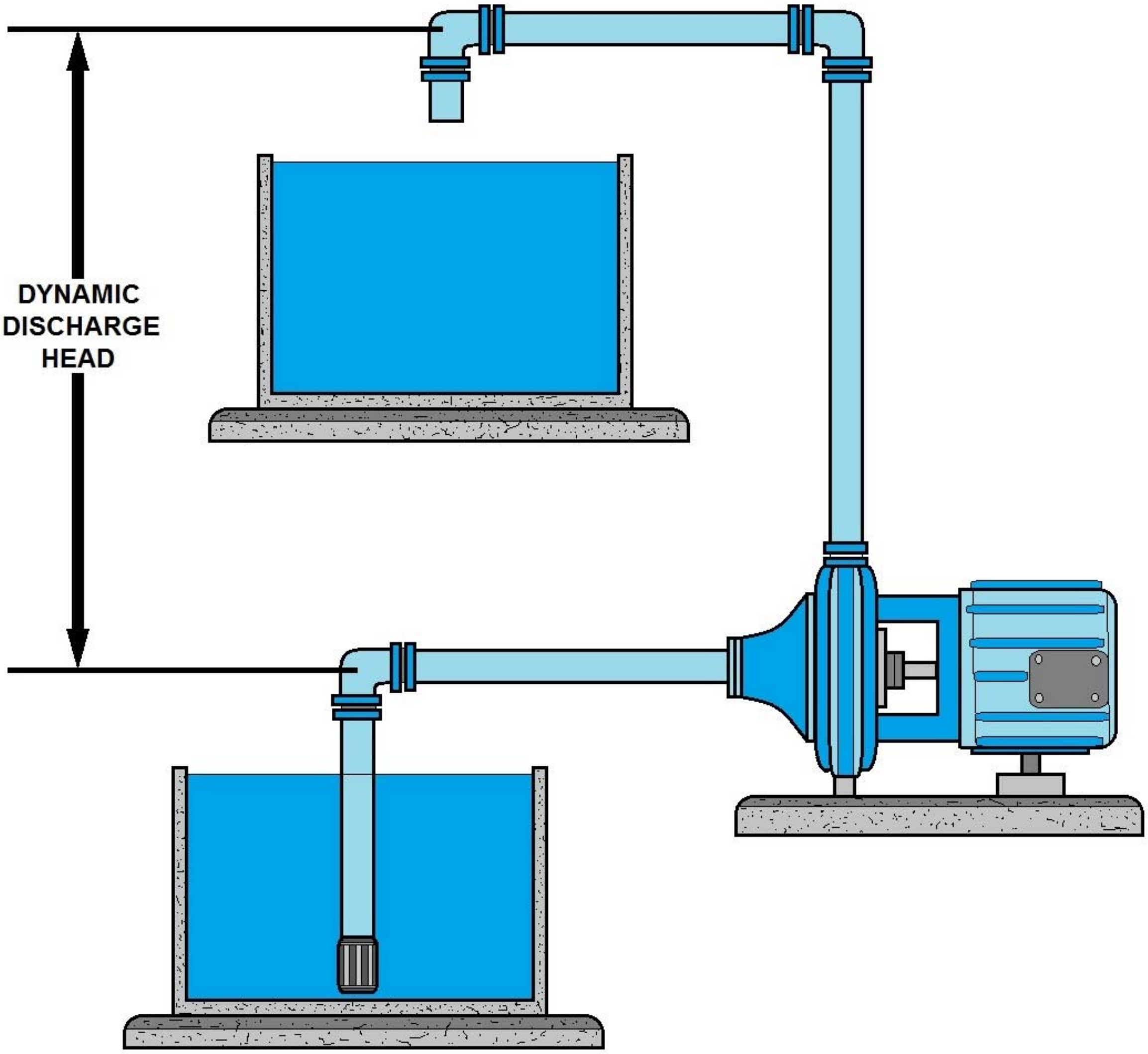
WATER HORSEPOWER
(THE ENERGY ADDED TO THE WATER BY THE PUMP ITSELF)



NET POSITIVE SUCTION HEAD

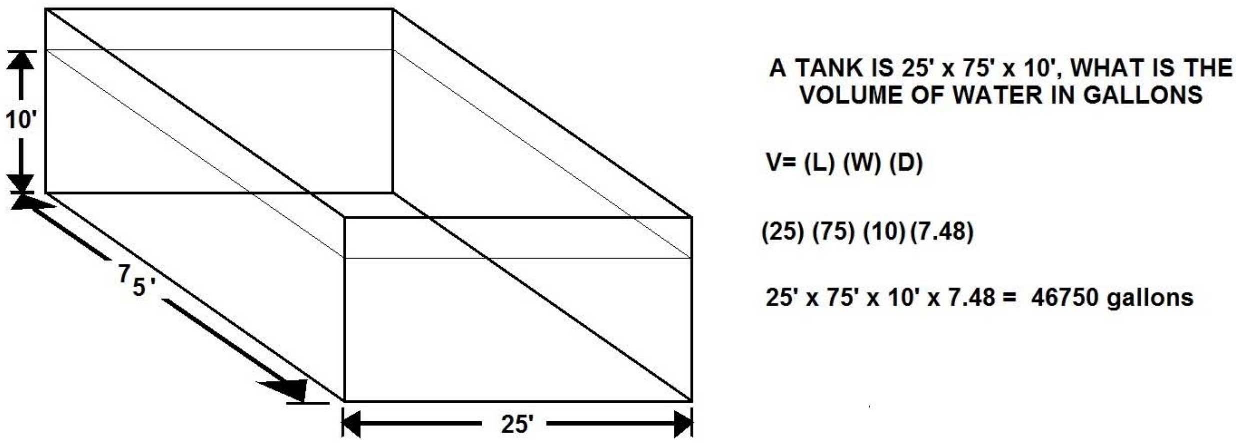


SUCTION HEAD (Suction Lift)



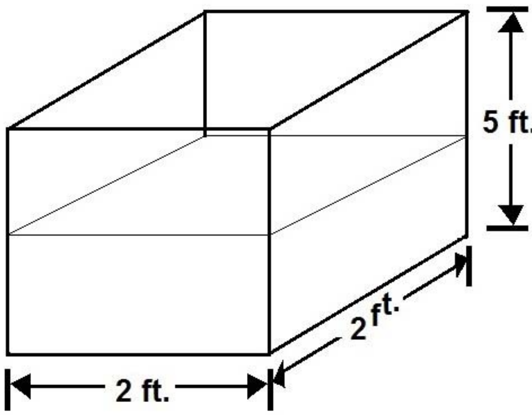
EXAMPLE OF DYNAMIC DISCHARGE HEAD
(The Static Discharge Head plus the friction in the discharge line)

Build it, Fill it and Dose it.



1. Convert 10 cubic feet to gallons of water.

There is 7.48 gallons in one cubic foot.
Diagrams are provided to help you visualize or figure the solution.



Convert 10 cu.ft. to gallons of water:

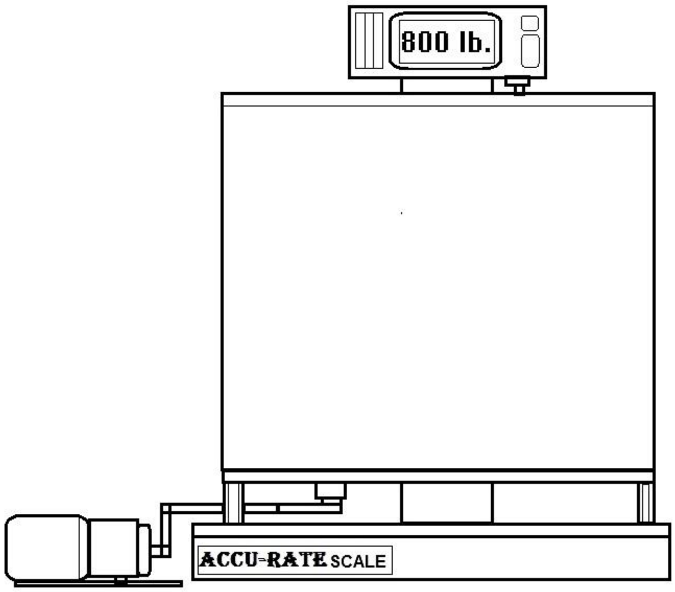
($10\ ft.^3$) (7.48)

Multiply $10\ ft.^3$ X 7.48 = gallons

CONVERTING CUBIC FEET TO GALLONS OF WATER

2. The liquid in a tank weighs 800 pounds, how many gallons are in the tank?

.



LIQUID IN A TANK WEIGHS 800 lbs. / HOW MANY GALLONS ARE IN THE TANK:

800 lbs. DIVIDED BY 8.34 lbs./gal.

$$\frac{800\text{lbs.}}{8.34\text{ lbs./gal.}} =$$

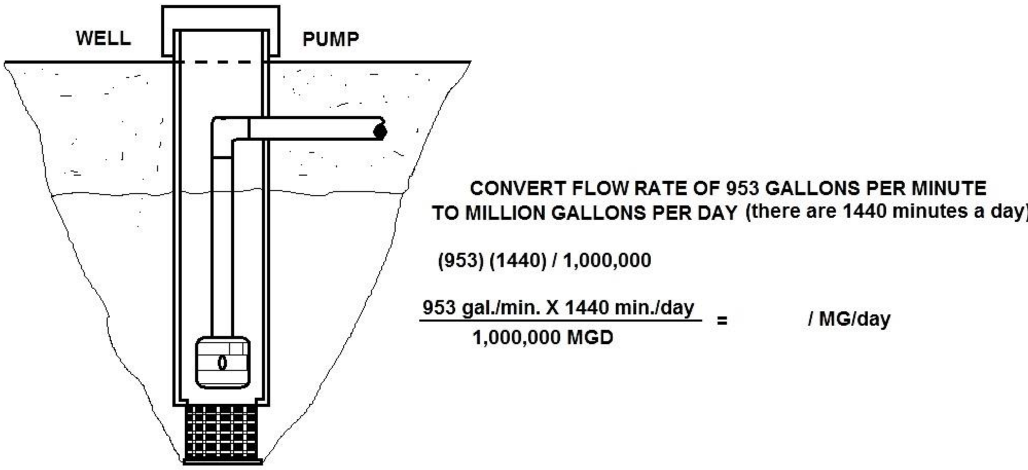
CONVERTING POUNDS TO GALLONS

Practice Questions, no answers provided

A1. Convert 75 cubic feet to gallons of water.

B1. The liquid in a tank weighs 50 pounds, how many gallons are in the tank?

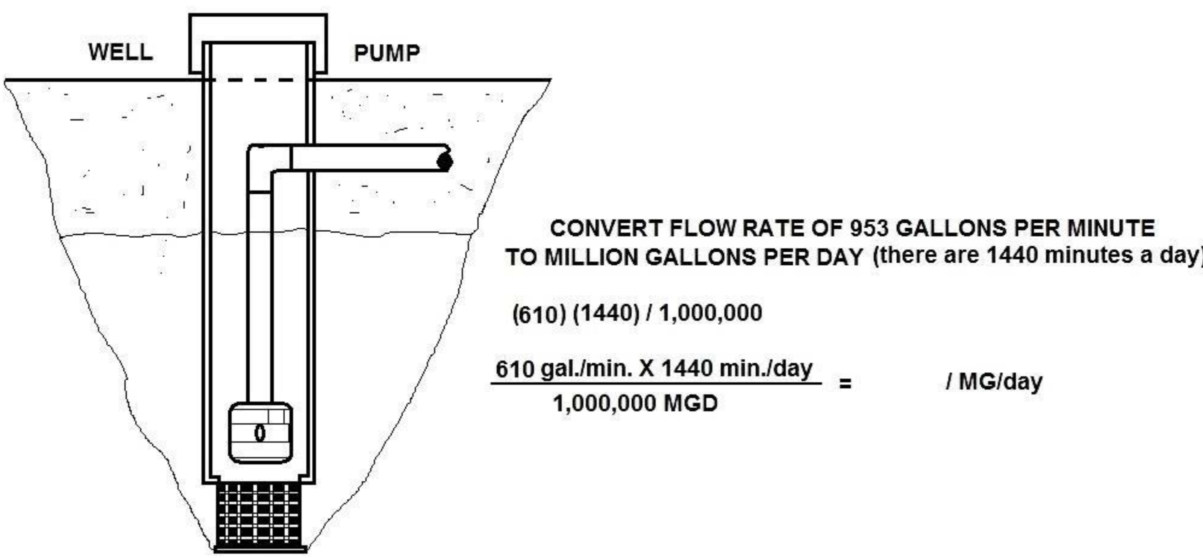
3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There is 1440 minutes in a day.



CONVERTING GALLONS PER MINUTE TO MILLION GALLONS PER DAY

4. Convert a flow rate of 610 gallons per minute to millions of gallons per day.

$$1 \text{ MG} = \frac{1{,}000{,}000 \text{ Gallons}}{24 \text{ Hour Fill time}}$$



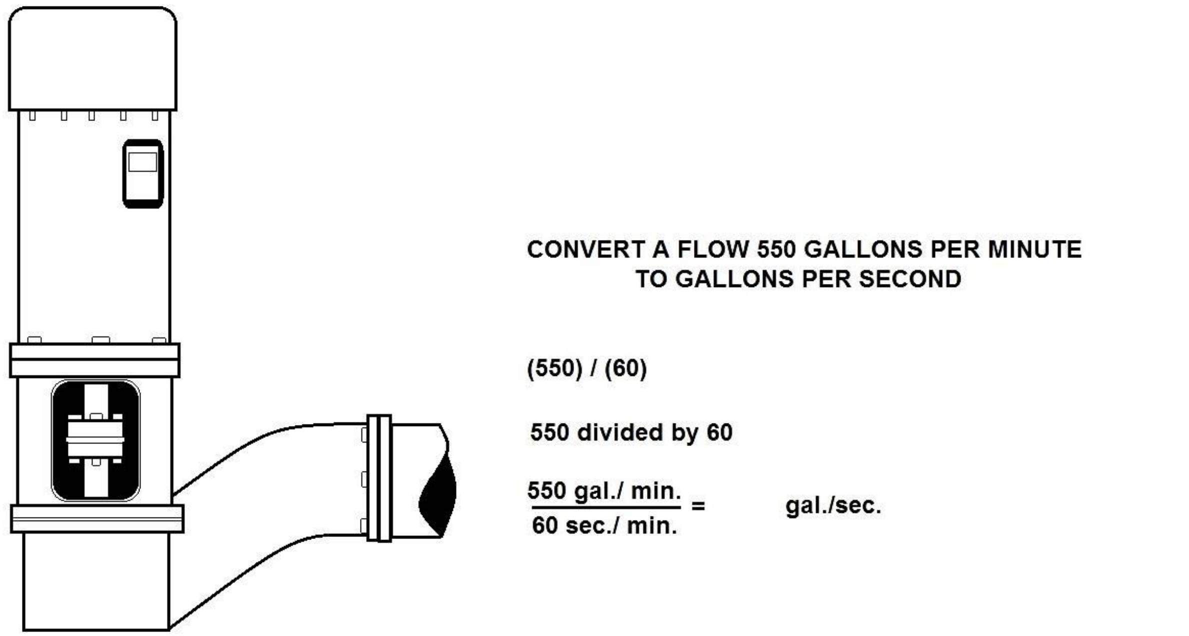
CONVERTING GALLONS PER MINUTE TO MILLION GALLONS PER DAY

Practice Questions, no answers provided

A2. Convert a flow rate of 14,750 gallons per minute to million gallons per day.

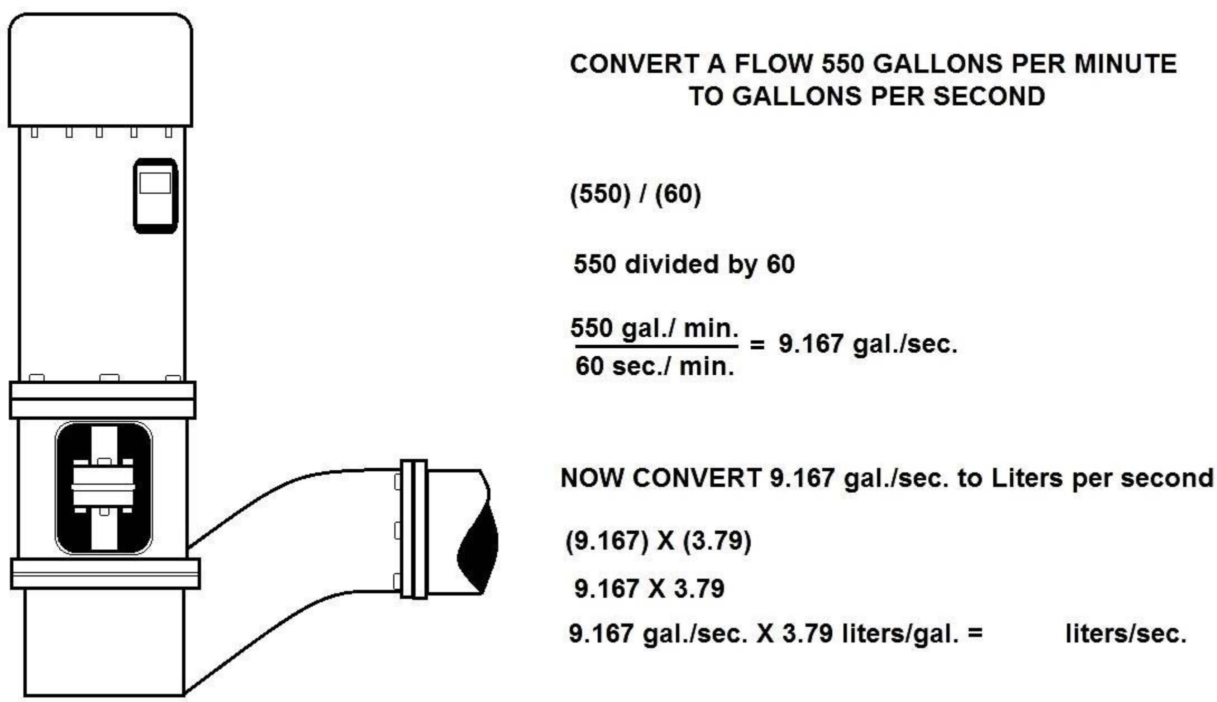
B2. Convert a flow rate of 5880 gallons per minute to millions of gallons per day.

5. Convert a flow of 550 gallons per minute to gallons per second.



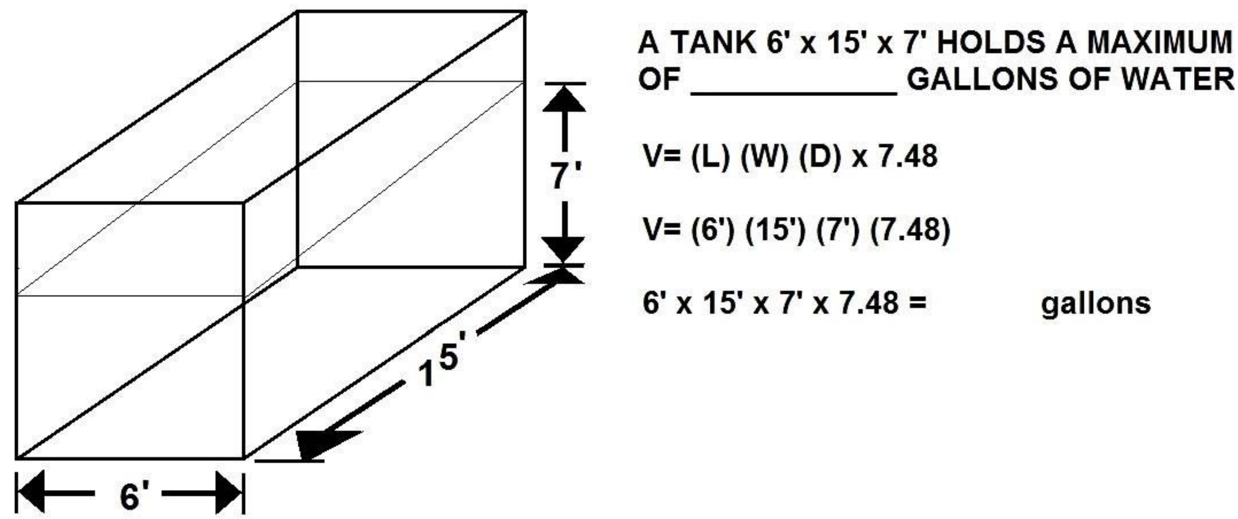
CONVERTING GALLONS PER MINUTE TO GALLONS PER SECOND

6. Now, convert this number to liters per second.



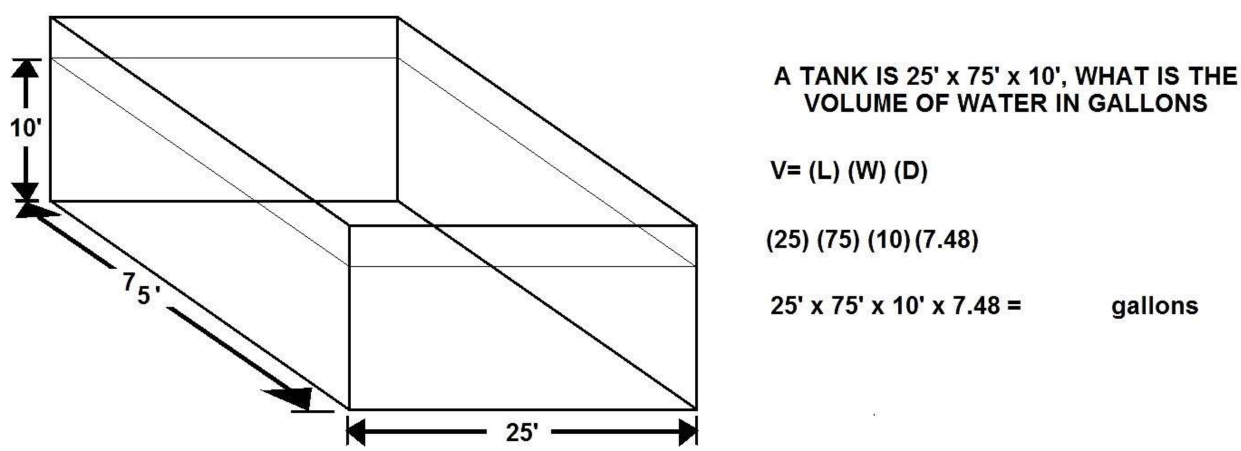
7. A tank is 6’ X 15’ x 7’ and can hold a maximum of ____________ gallons of water.

V= (L) (W) (D) X 7.48 =



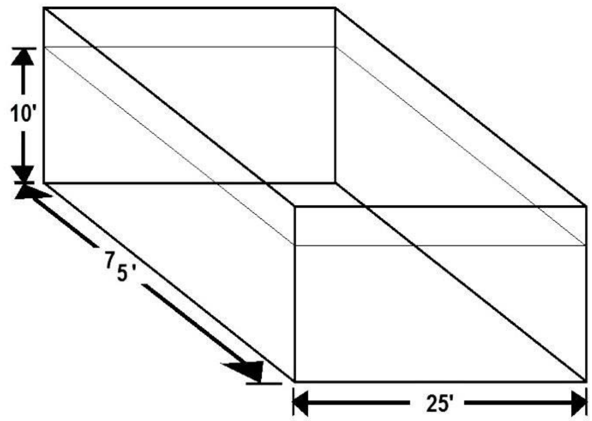
8. A tank is 25’ X 75’ X 10’ what is the volume of water in gallons?

V= (L) (W) (D) X 7.48 =



9. In Liters?

V= (L) (W) (D) X 7.48 =_________ X 3.785



A TANK IS 25' x 75' x 10', WHAT IS THE VOLUME OF WATER IN LITERS

V= (L) (W) (D)

(25) (75) (10)(7.48)

25' x 75' x 10' x 7.48 = 46750 gallons

1 GALLON = 3.79 LITERS

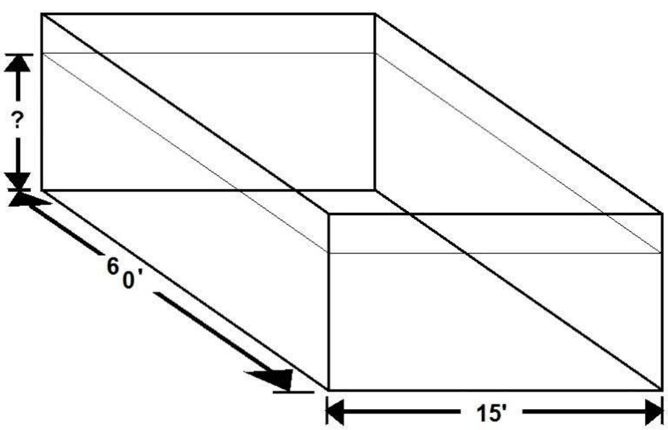
V= (L) (W) (D) X 7.48= 46750 gallons X 3.79

V= Liters

Metric information is found in the front of the manual after the Table of Contents.

10. A tank holds 67,320 gallons of water. The length is 60’ and the width is 15’. How deep is the tank?

Gallons______ ÷ 7.48 = _______ 60 X 15 =



A TANK HOLDS 67,320 GALLONS OF WATER. THE LENGTH IS 60' AND THE WIDTH IS 15'. HOW DEEP IS THE TANK?

Gallons <u>67,320</u> / 7.48 = <u>9000 gal.</u>

60' X 15' = 900 ft.

$$\frac{\textbf{9000 gal.}}{\textbf{900 ft.}} = \quad \textbf{ft.}$$

Practice Questions, no answers provided

A3. Convert a flow of 733 gallons per minute to gallons per second.

B3. Now, convert this number to liters per second.

Metric information is found in the front of the manual after the Table of Contents.

C3. A tank is 20’ X 20’ x 40’ and can hold a maximum of ____________ gallons of water.

D3. In Liters?

V= (L) (W) (D) X 7.48 =_________ X 3.79 l/gal

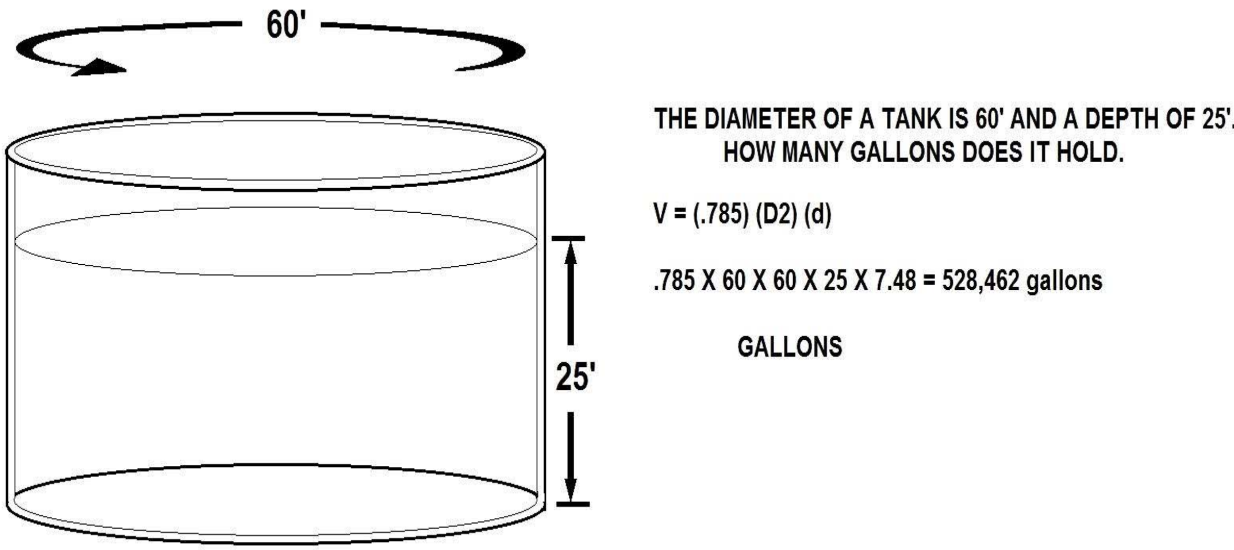
E3. A tank holds 85,000 gallons of water. The length is 75’ and the width is 14’. How deep is the tank?

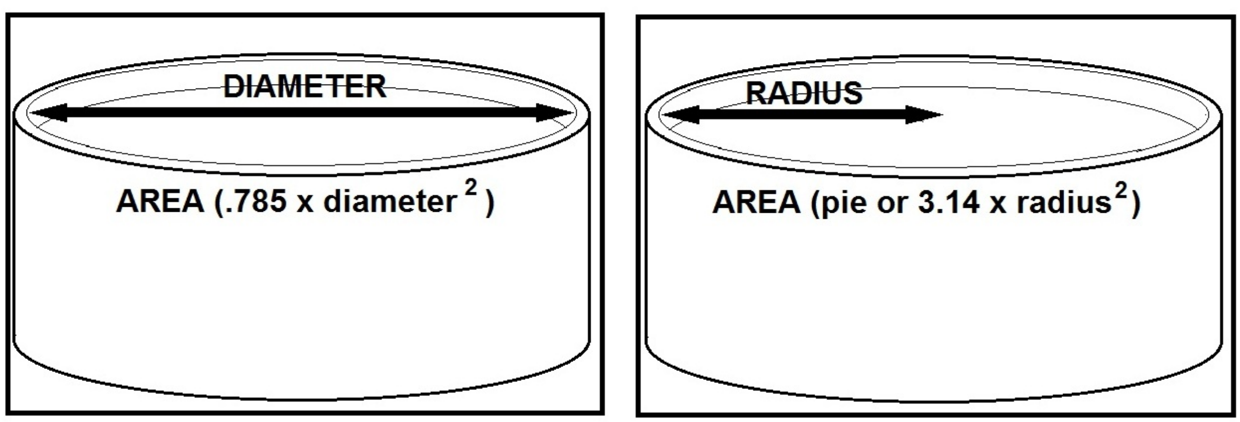
11. The diameter of a tank is 60’ and the depth is 25’. How many gallons does it hold?

Cylinder Formula

V= (.785) (D^2) (d)

.785 X 60’ X 60’ X 25’ X 7.48 =





Diagrams are provided to help you visualize or figure the solution.

Practice Questions, no answers provided

A4. The diameter of a tank is 30' and the depth is 5'. How many gallons does it hold?

B4. The diameter of a tank is 160' and the depth is 30'. How many gallons does it hold?

C4. The diameter of a tank is 33' and the depth is 20'. How many gallons does it hold?

D4. The diameter of a tank is 5' and the depth is .5'. How many gallons does it hold?

Cubic Feet Information
There is no universally agreed symbol but the following are used:

cubic feet, cubic foot, cubic ft
cu ft, cu feet, cu foot
ft_3, feet 3, foot 3
feet3, foot3, ft_3
feet/-3, foot/-3, ft/-3

Water/Wastewater Treatment Production Math Numbering System

In water/wastewater treatment, we express our production numbers in Million Gallon numbers. Example 2,000,000 or 2 million gallons would be expressed as 2 MG or 2 MGD.

$$1\text{ MG} = \frac{1{,}000{,}000\text{ Gallons}}{24\text{ Hour Fill time}}$$

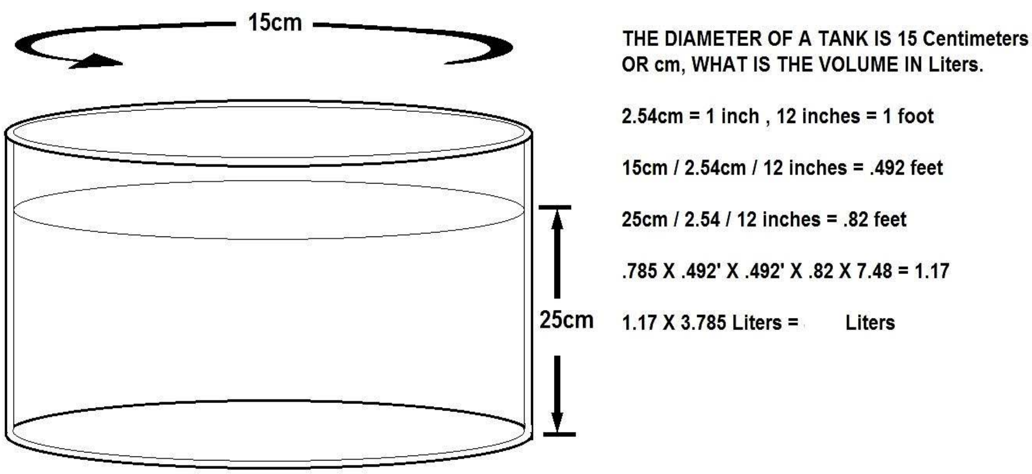
2.4 Hours

Hint. A million has six zeroes; you can always divide your final number by 1,000,000 or move the decimal point to the left six places. Example 528,462 would be expressed .56 MGD.

12. The diameter of a tank is 15 Centimeters or cm and the depth is 25 cm, what is the volume in liters?

2.54cm = 1 inch, 12 inches = 1 foot
15 cm ÷ 2.54 cm ÷ 12 inches = .492 feet

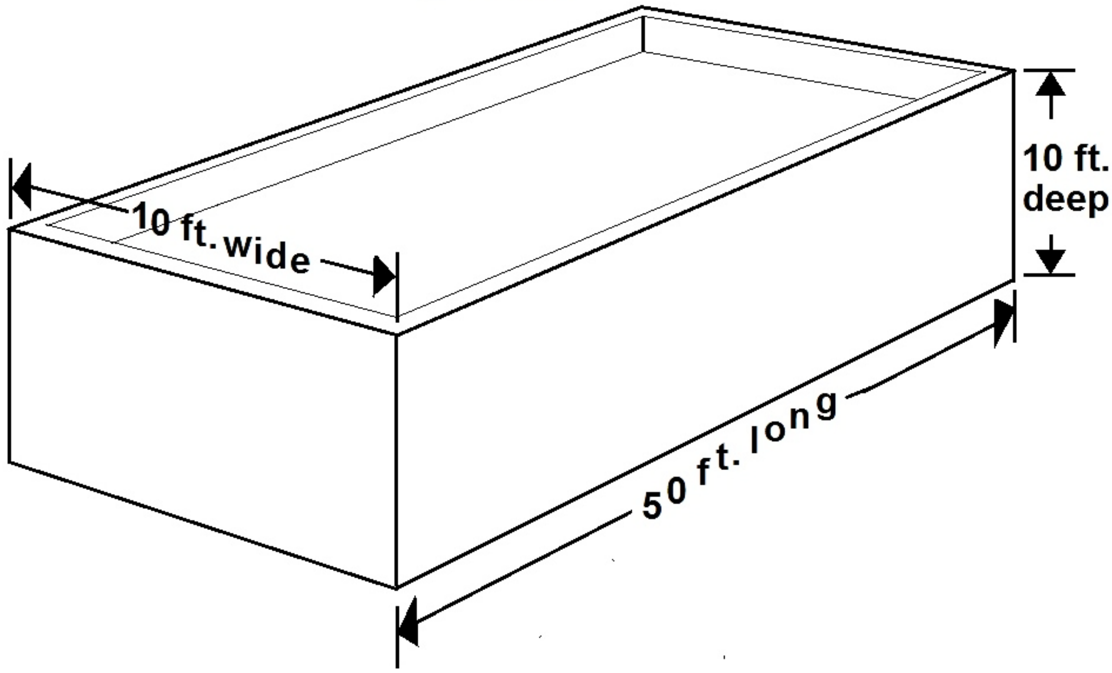
.785 X .492’ X .492’ X _____’ =______ X 7.48 = _______ X 3.785 L =

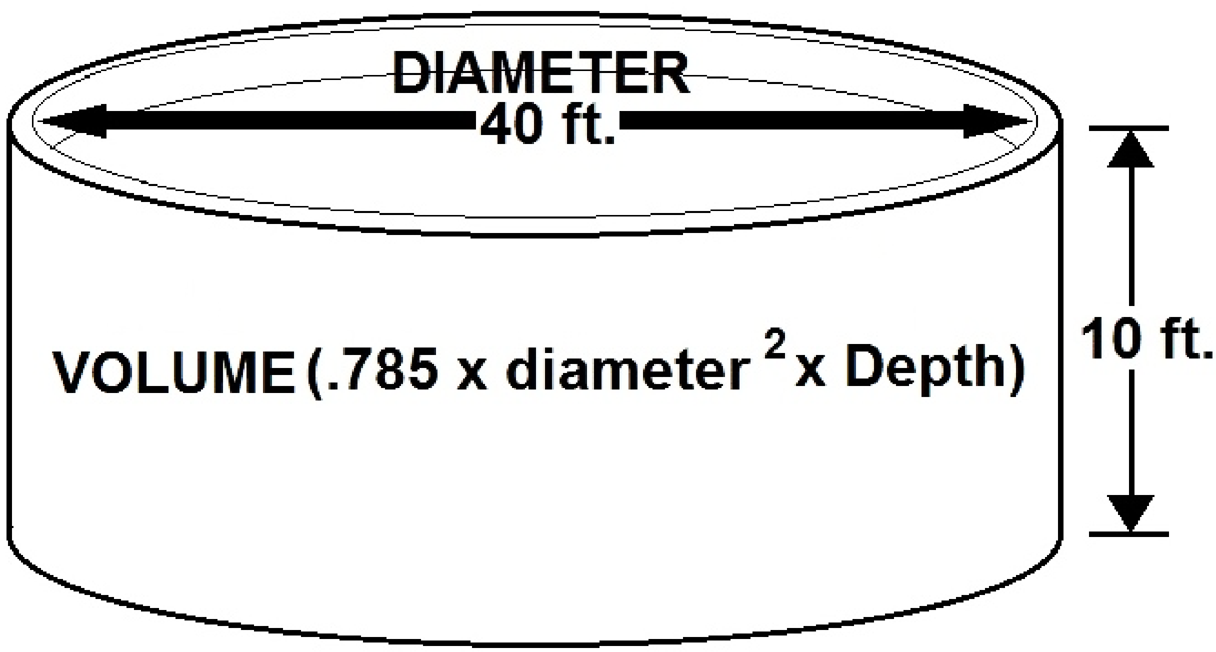


See Table of Contents for more on the Metric System.

VOLUME (Length x Width x Depth)

X^3 Cubic





Flow and Velocity Exercises

This depends on measuring the average velocity of flow and the cross-sectional area of the channel and calculating the flow from:

$$Q(m^3/s) = A(m^2) \times V(m/s)$$

Or

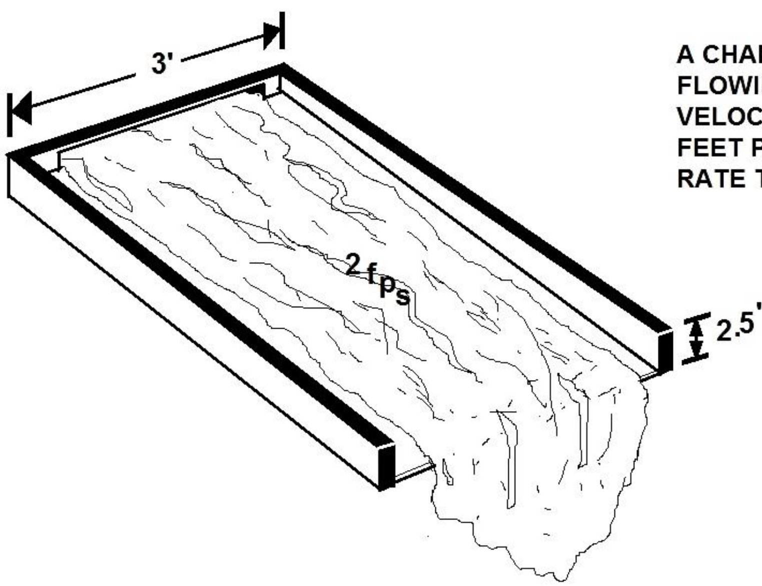
$$Q = A \times V$$

Q CFM = Cubic Ft, Inches, Yards of time, Sec, Min, Hrs, Days
A = Area, squared Length X Width
V f/m = Inch, Ft, Yards, Per Time, Sec, Min, Ft or Speed

13. A channel is 3 feet wide and has water flowing to a depth of 2.5 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?

Q = A X V

Q = 7.5 sq. ft. X 2 fps *What is Q?*
A= 3’ X 2.5’ = 7.5
V= 2 fps



A CHANNEL IS 3 FEET WIDE AND HAS WATER FLOWING TO A DEPTH OF 2.5 FEET. IF THE VELOCITY THROUGH THE CHANNEL IS 2 fps OR FEET PER SECOND,WHAT IS THE cfs FLOW RATE THROUGH THE CHANNEL.

Q = A X V

A = 3ft. X 2.5ft

A = 7.5 ft^2

V = 2ft./sec.

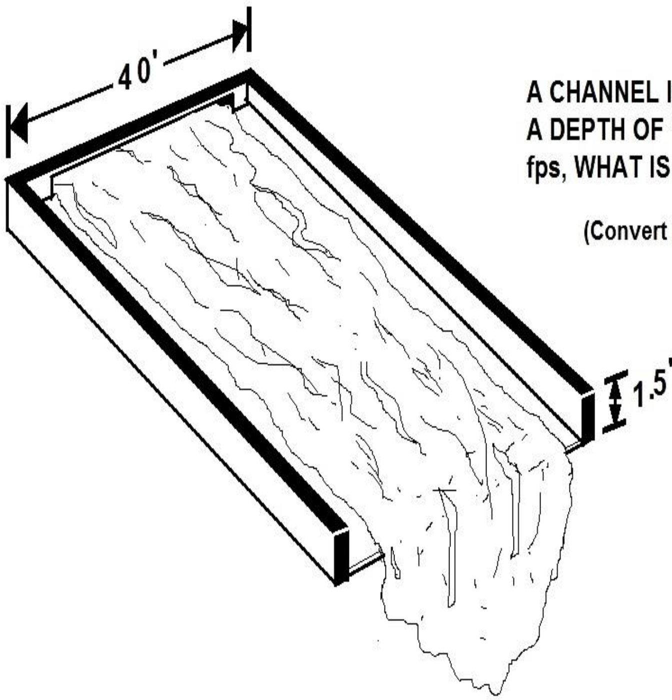
Q = 7.5 ft.^{2} X 2ft./sec.

Q = /sec.

14. A channel is 40 inches wide and has water flowing to a depth of 1.5 ft. If the velocity of the water is 2.3 fps, what is the cfs flow in the channel? Q = A X V
First we must convert 40 inches to feet.

40 ÷ 12” = 3.333 feet

A = 3.333’ X 1.5’ = 4.999 or round up to 5
V = 2.3 fps
We can round this answer up.



A CHANNEL IS 40 INCHES WIDE AND HAS WATER FLOWING TO A DEPTH OF 1.5 FEET. IF THE VELOCITY OF THE WATER IS 2.3 fps, WHAT IS THE cfs FLOW IN THE CHANNEL.

(Convert inches to feet first by dividing by 12 to get feet)

Q = A X V

A = (40/12 = 3.33ft.) X (1.5ft)

A = 4.995 (Round to 5)

V = 2.3 ft/sec.

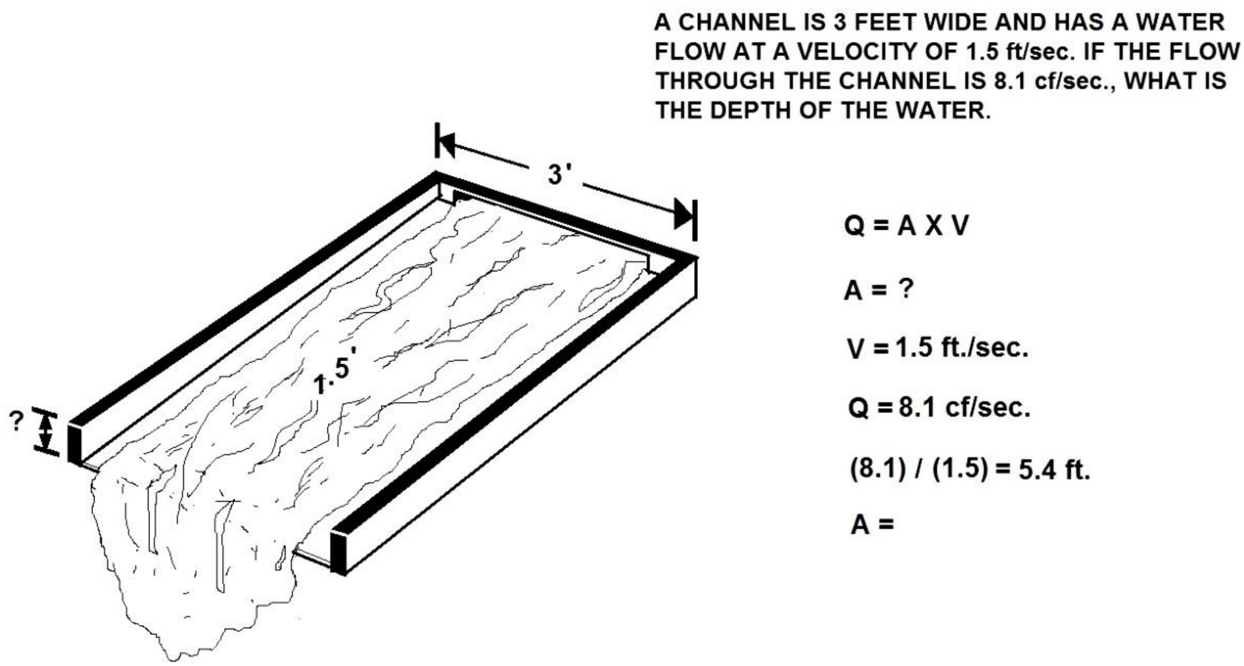
Q = 2.3 ft/sec. X 5ft

Q = cf/sec.

15. A channel is 3 feet wide and has a water flow at a velocity of 1.5 fps. If the flow through the channel is 8.1 cfs, what is the depth of the water?

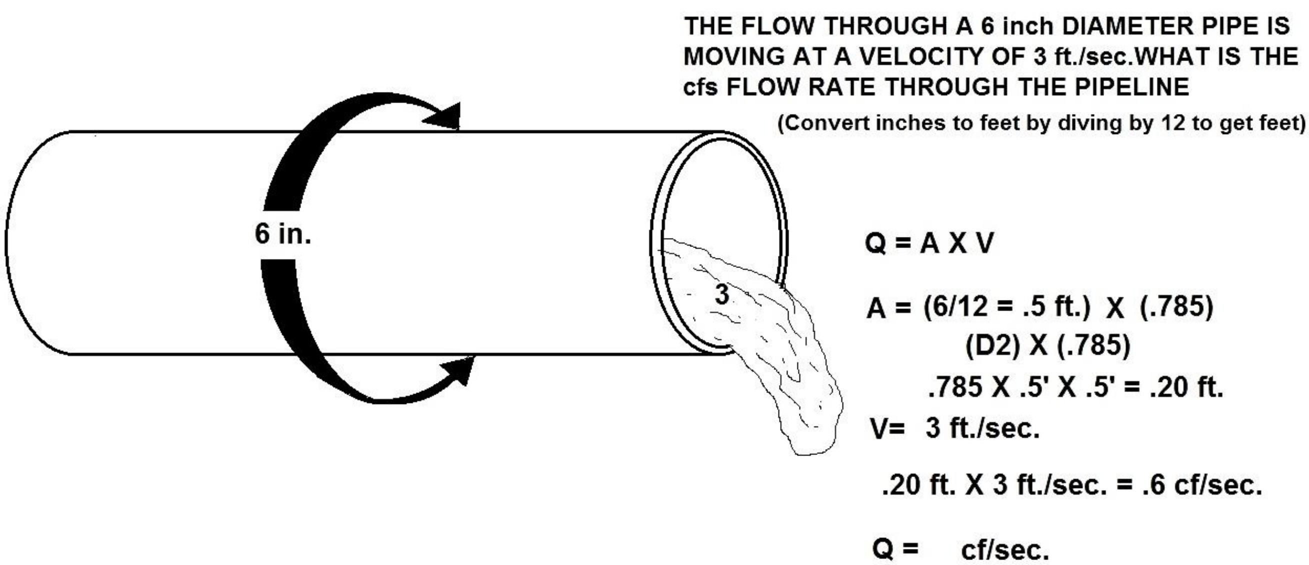
$$Q = 8.1 \text{ cfs}$$
$$V = 1.5 \text{ fps}$$
$$A = ?$$

8.1 ÷1.5 = _______ Total Area



16. The flow through a 6 inch diameter pipe is moving at a velocity of 3 ft/sec. What is the cfs flow rate through the pipeline?

Q =
A = .785 X .5' X .5' =
V = 3 fps

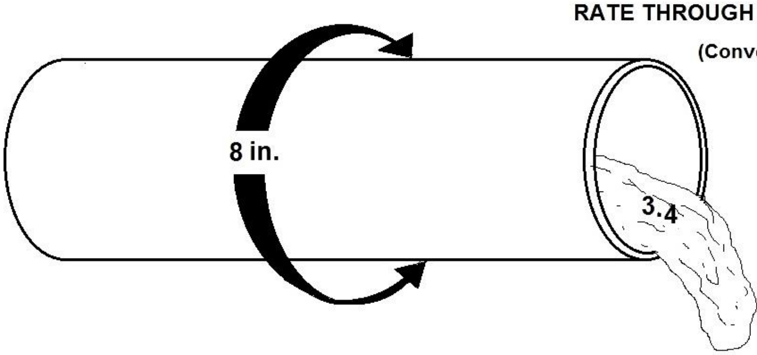


17. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

Q = ______ cfs X 60 sec/min X 7.48 = ___________ gpm
A = .785 X .667’ X .667’
V = 3.4 fps

AN 8 inch DIAMETER PIPE HAS WATER FLOWING AT A VELOCITY OF 3.4 ft./sec. WHAT IS THE gpm (gal./min.) FLOW RATE THROUGH THE PIPE.

(Convert inches to feet by diving by 12 to get feet)



Q = A X V

A = (8/12 = .667 ft.) (.785)
(D2) X (.785)
.785 X .667' X .667' = .35 ft.

V= 3.4 ft/sec.

.35 ft. X 3.4 ft./sec. = 1.19 cf/sec.

Q = 1.19 cf/sec. X 60 sec./min. X 7.48 =

Q = gal./min.

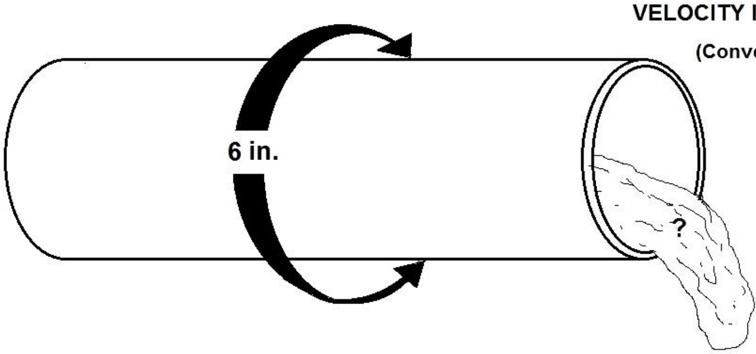
18. A 6 inch diameter pipe delivers 280 gpm. What is the velocity of flow in the pipe in ft/sec?

Take the water out of the pipe. 280 gpm ÷ 7.48 ÷ 60 sec/min = ________ cfs

Q =
A = .785 X .5’ X .5’ =
V =

A 6 inch PIPE DELIVERS 280 gal./min. WHAT IS THE VELOCITY IN THE PIPE IN ft./sec.

(Convert inches to feet by diving by 12 to get feet)



Q = A X V

A = (6/12 = .5 ft.) (.785)
(D2) (.785)
.785 X .5' X .5' = .20 ft.

V = ?

Q = 280 gal./min.

(Take the water out of the pipe)

Q = (280 gal./min.) / (7.48) / (60 sec./min.) = .623 cf/sec.

(Divide the Q by the A to get the V)

(.623 cf/sec.) / (.20 ft.) =

V = ft./sec.

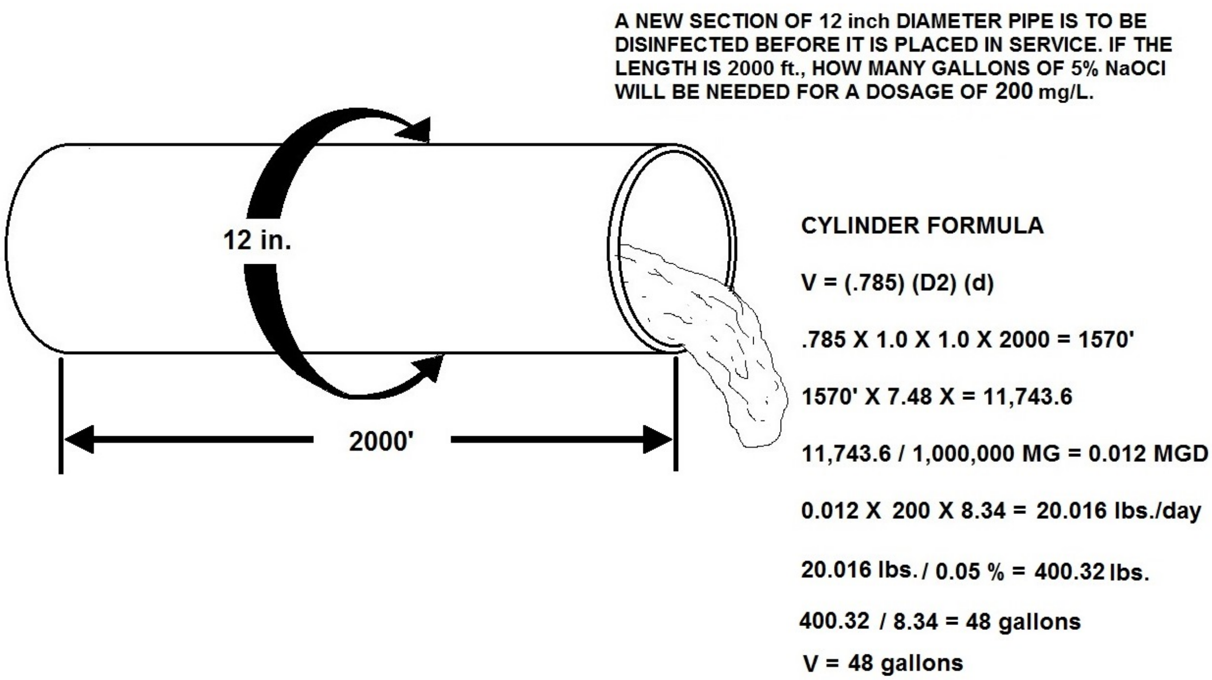
19. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

Cylinder Formula
V= (.785) (D^2) (d)

.785 X 1' X 1' X 2000' = _______ cu.ft. X 7.48 = ______ ÷ 1,000,000 = ___________MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal if 100% concentrate. If not, divide the lbs/day by the given %

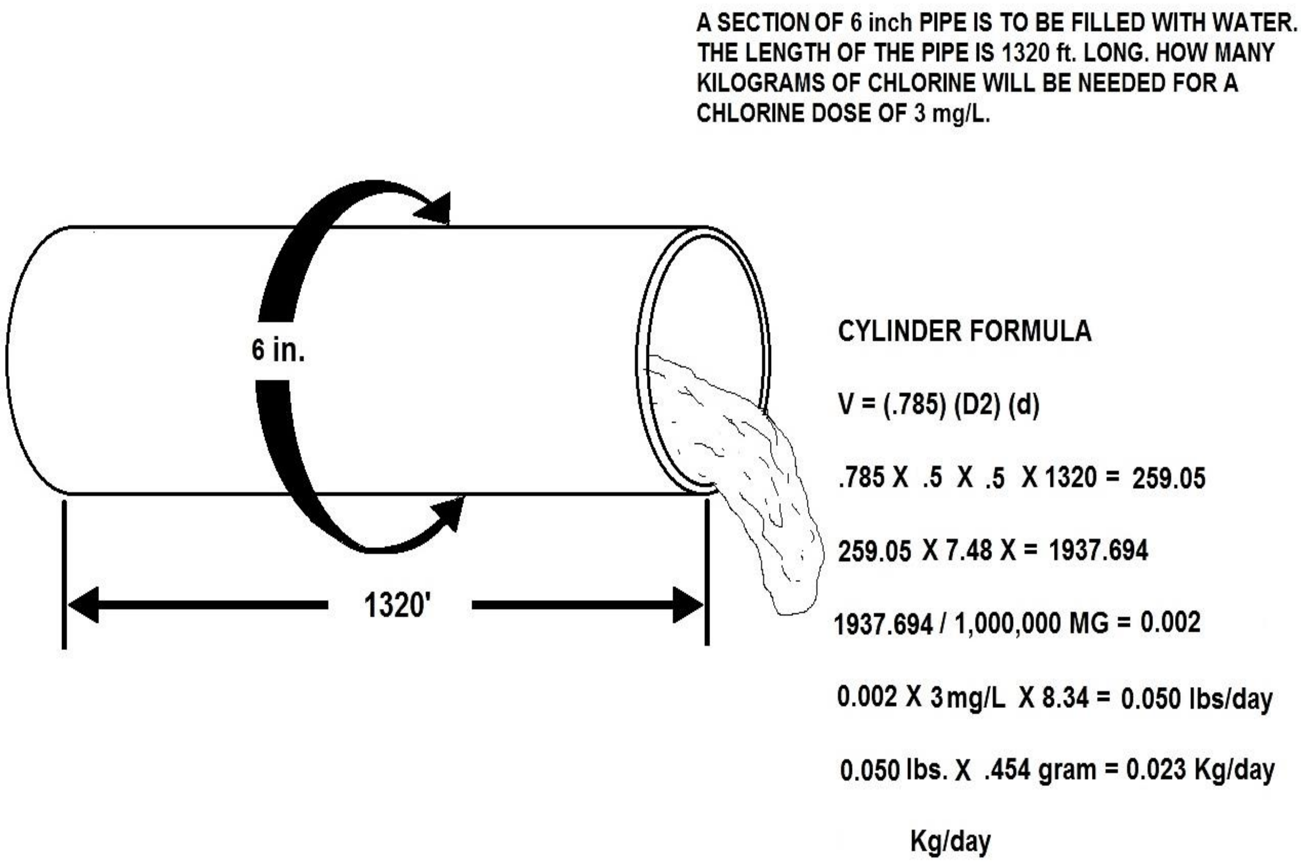
0.0117436 MG X 200 mg/L X 8.34 =_________ lbs/day ÷ .05 =



20. A section of 6 inch diameter pipe is to be filled with water. The length of the pipe is 1320 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 3 mg/L?

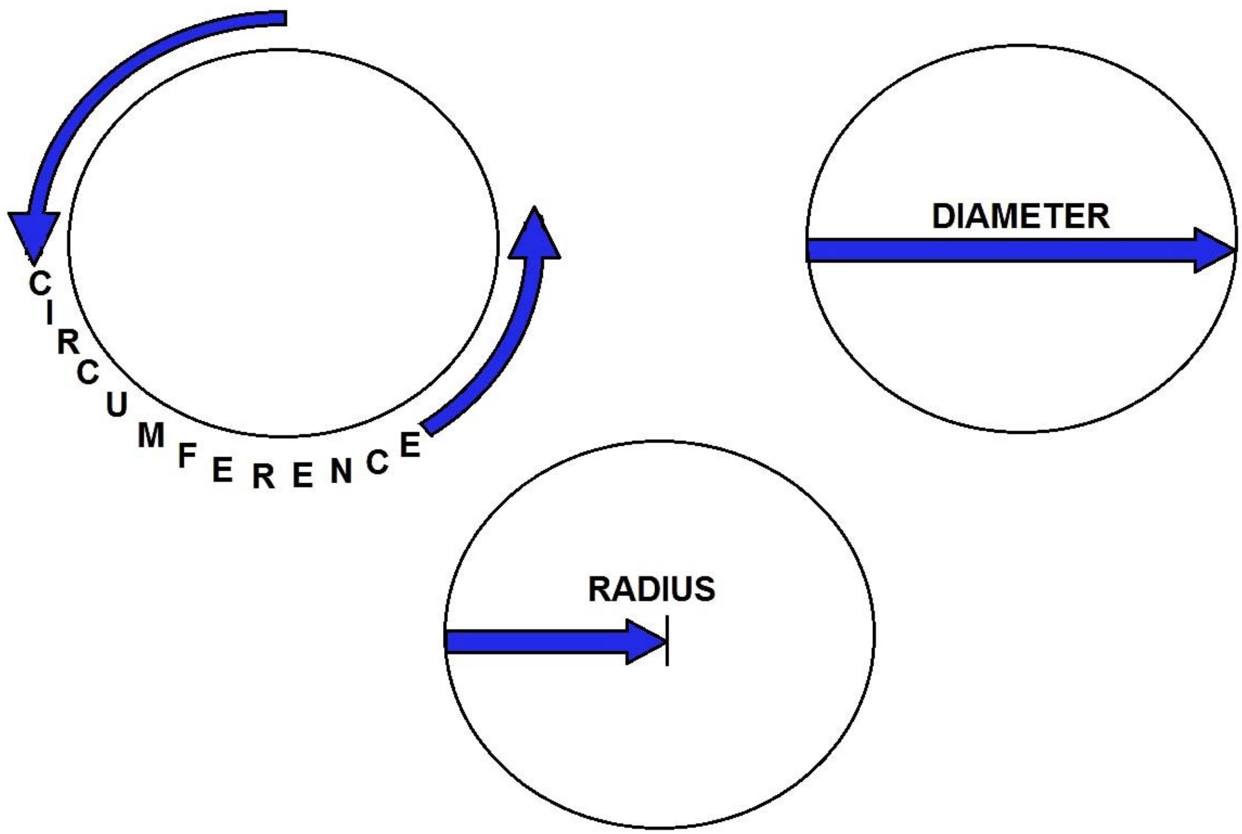
.785 X .5’ X .5’ X 1320’ X 7.48 =_____________ Make it MGD

Pounds per day formula = Flow X Dose X 8.34 X .454 Grams per pound



Math Exercise Answers

1. 74.8
2. 800 ÷ 8.34 = 95.92 gallons
3. 1372320 or 1.3 MGD
4. 610 X 1441 = 878400 or 0.87 MGD
5. 550 ÷ 60 = 9.167 gpm
6. 9.167 X 3.785 = 34.697 Liters
7. 630 Area 4712.4 gallons
8. 18,750 cu. ft. X 7.48 = 140250 gallons
9. 177182.5
10. 10 feet deep
11. 528462 or .5 MG
12. 1.166 Gallons X 3.785 = 4.4131 Liters
13. 15 cfs
14. 11.5 cfs
15. 5.4
16. .58875 or .6 cfs
17. 534.7 or 533 gpm
18. 3.115 or 3.2 ft/sec
19. 46.9 gal
20. .02 kg



Practice Questions, no answers provided

A5. A channel is 5 feet wide and has water flowing to a depth of 2 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?

$$Q = A \times V$$

B5. A channel is 36 inches wide and has water flowing to a depth of 2.5 ft. If the velocity of the water is 2.0 fps, what is the cfs flow in the channel?

$$Q = A \times V$$

C5. A channel is 2 feet wide and has a water flow at a velocity of 3.5 fps. If the flow through the channel is 5.5 cfs, what is the depth of the water?

D5. The flow through a 8 inch diameter pipe is moving at a velocity of 5 ft/sec. What is the cfs flow rate through the pipeline?

E5. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

F5. A 6 inch diameter pipe delivers 55 gpm. What is the velocity of flow in the pipe in ft/sec?

G5. A new section of 18 inch diameter pipe is to be disinfected before it is placed in service. If the length is 5000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

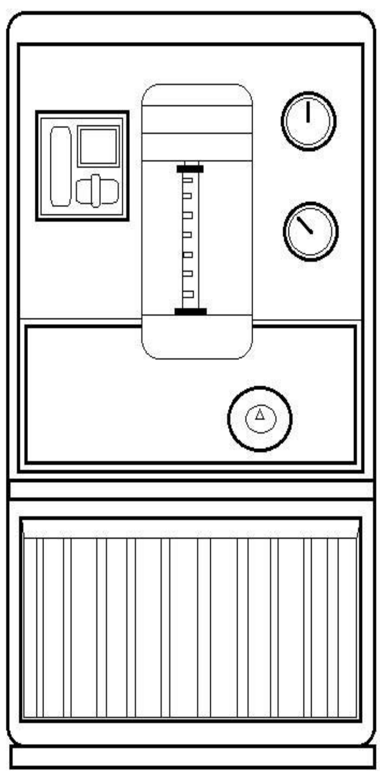
Cylinder Formula
$V= (.785) (D^2) (d)$

H5. A section of 18 inch diameter pipe is to be filled with water. The length of the pipe is 1200 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 2 mg/L?

Pounds per day formula = Flow X Dose X 8.34 X .454 Grams per pound

21. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 3.4 MGD with a chlorine dose of 3.35 mg/L? Answer in rear of this section.

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

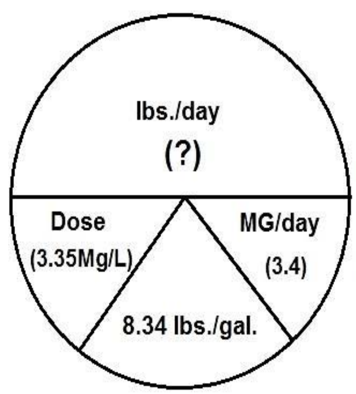


DETERMINE THE CHLORINATOR SETTING IN POUNDS PER 24 HOUR PERIOD TO TREAT 3.4 MGD WITH A CHLORINE DOSE OF 3.35 mg/L.

FLOW = (MGD) (DOSE) (Mg/L) X 8.34 lbs/gal.

3.4 MGD X 3.35 Mg/L = 94.9926 lbs./day (round to 95)

lbs./day



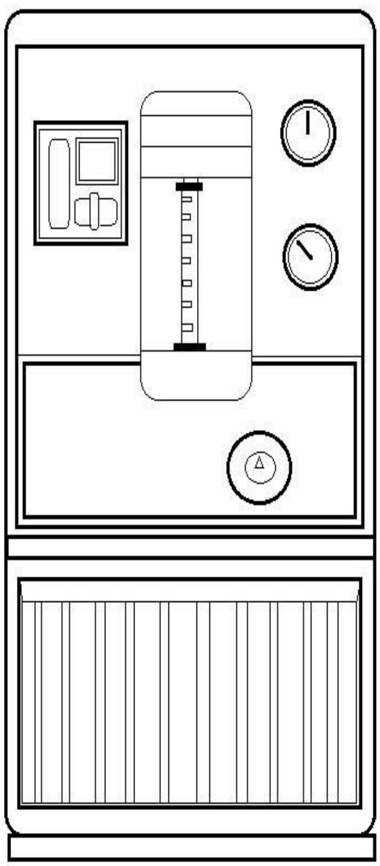
PIE CHART FORMULA CAN BE USED TO CALCULATE lbs./day.

(DOSE) X (8.34) X (MG/day) = lbs./day

22. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 85 GPM. Approximately how much will odor control cost annually if chlorine is $0.17 per pound?

85 gpm X 1440 min/day = _____________ gpd ÷ 1,000,000 = __________ MGD

______ MGD X 15 mg/L X 8.34 lbs/gal X $0.17 per pound X 365 days/year =



TO CORRECT AN ODOR PROBLEM, YOU USE CHLORINE CONTINUOUSLY AT A DOSAGE OF 15 mg/L AND A FLOW RATE OF 85 GPM. APPROXIMATELY HOW MUCH WILL ODOR CONTROL COST ANNUALLY IF CHLORINE IS $0.17 PER POUND.

CONVERT GPM TO gal/day.: 85 GPM X 1440 min./day = 122,400 gal./day.

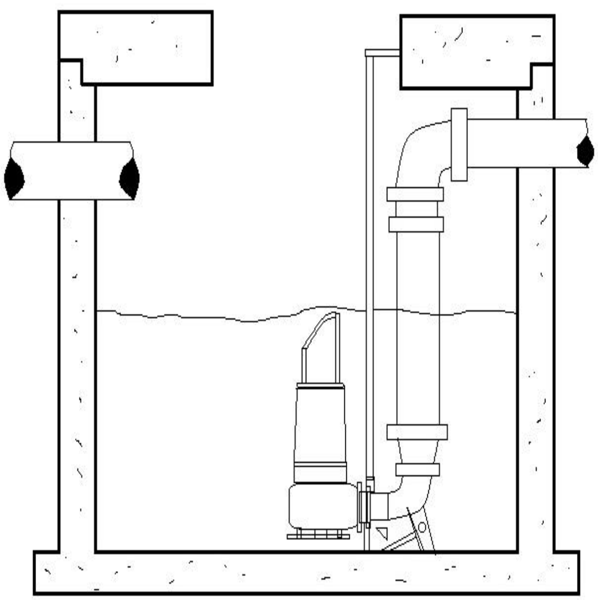
NOW CONVERT TO MGD: 122,400 divided by 1,000,000 = .1224 MGD.

.1224 MGD X 15 mg/L X 8.34 lbs./gal. X $ 0.17 per/Lb. X 365 days/year =

COST =

23. A wet well measures 8 feet by 10 feet and 3 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).

Build it, fill it, and do what it says, hint: X 9 X 24



A WET WELL MEASURES 8 feet BY 10 feet AND 3 feet IN DEPTH BETWEEN THE HIGH AND LOW LEVELS. A PUMP EMPTIES THE WET WELL BETWEEN THE HIGH AND LOW LEVELS 9 TIMES PER HOUR, 24 HOURS A DAY. NEGLECTING INFLOW DURING PUMP CYCLE, CALCULATE THE FLOW INTO THE PUMP STATION IN MILLION OF GALLONS PER DAY (MGD).
(Build it / Fill it / and Do What it says, hint: X 9 X 24)

(L) (W) (d) = (8) X (10) X (3) = 240 ft3
(CONVERT TO GALLONS: X 7.48)

240 ft3 X 7.48 = 1795.2 gals.

DETERMINE HOW MANY CYCLES IN 24 hrs.:
9 times hour X 24 hrs./day = 216 times/day.

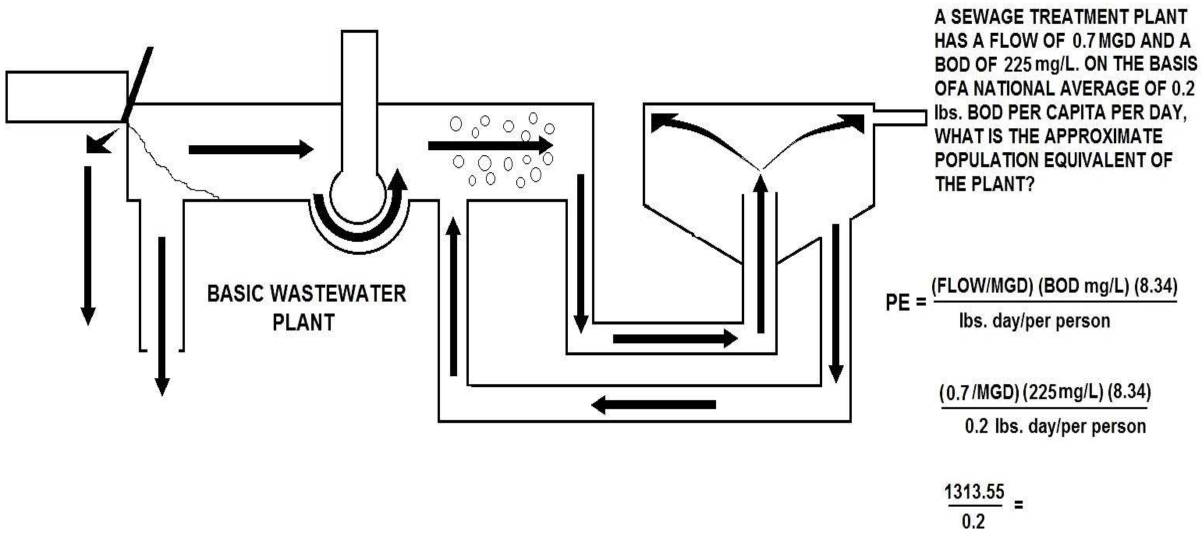
1795.2 gals. X 216 times/day = 387763.2 gals./day

CONVERT THIS TO MGD BY DIVIDING BY 1,000,000.

387763.2 gals./day / 1,000,000 = .388 MGD

INFLOW = MGD

24. A sewage treatment plant has a flow of 0.7 MGD and a BOD of 225 mg/L. On the basis of a national average of 0.2 lbs BOD per capita per day, what is the approximate population equivalent of the plant?

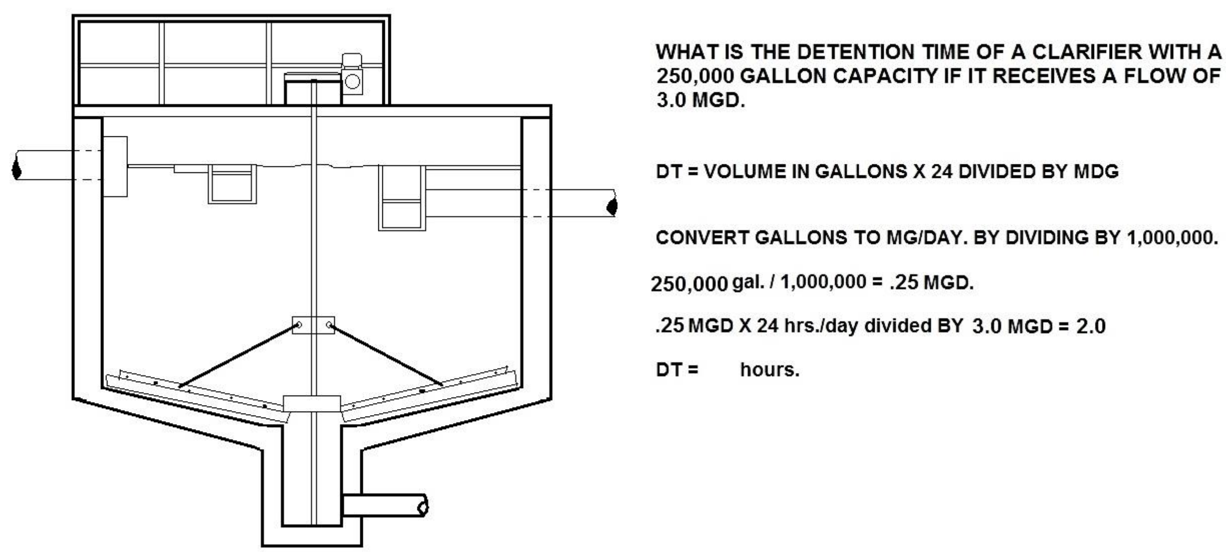


25. What is the detention time of a clarifier with a 250,000 gallon capacity if it receives a flow of 3.0 MGD?

DT= Volume in Gallons X 24 Divided by MGD

.25 MG X 24 hrs ÷ 3.0 MGD =________ Hours of DT

Always convert gallons to MG

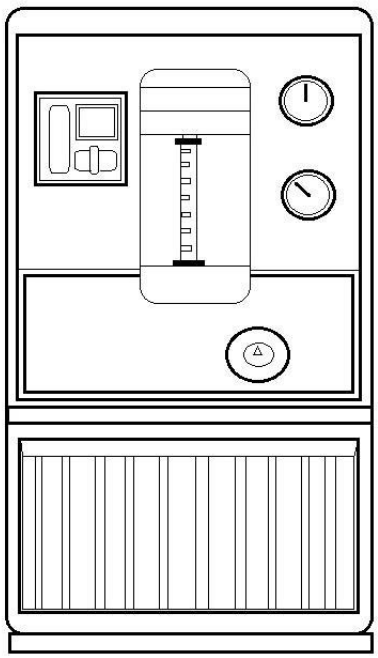


Answers 21. 94.9 lbs/day, 22. $950.12, 23. .388 or .39 MGD, 24. 6567.75, 25. 2 hrs

Treatment Plant Practice Questions

A6. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 5.4 MGD with a chlorine dose of 2.35 mg/L?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

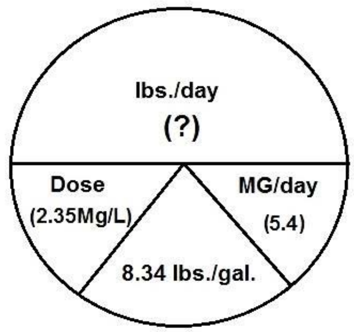


DETERMINE THE CHLORINATOR SETTING IN POUNDS PER 24 HOUR PERIOD TO TREAT 5.4 MGD WITH A CHLORINE DOSE OF 2.35 mg/L.

FLOW = (MGD) (DOSE) (Mg/L) X 8.34 lbs/gal.

5.4 MGD X 2.35 Mg/L = 105.83 lbs./day (round to 106)

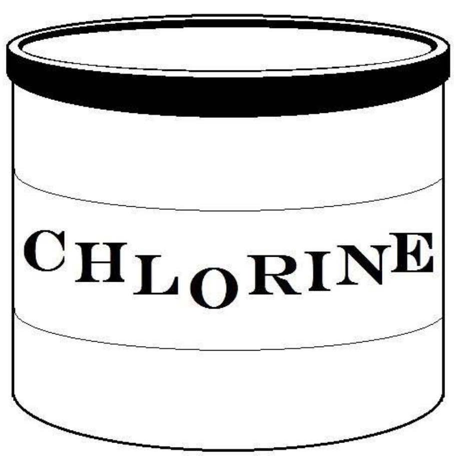
106 lbs./day



PIE CHART FORMULA CAN BE USED TO CALCULATE lbs./day.

(DOSE) X (8.34) X (MG/day) = lbs./day

B6. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 7 GPM. Approximately how much will odor control cost annually if chlorine is $0.15 per pound?



TO CORRECT AN ODOR PROBLEM, YOU USE CHLORINE CONTINUOUSLY AT A DOSAGE OF 15 mg/L AND A FLOW RATE OF 7 GPM. APPROXIMATELY HOW MUCH WILL ODOR CONTROL COST ANNUALLY IF CHLORINE IS $0.15 PER POUND?

FIRST CONVERT gal./min TO MGD

(7gal./min.) (1440 min./day) = 10,080 gal./day

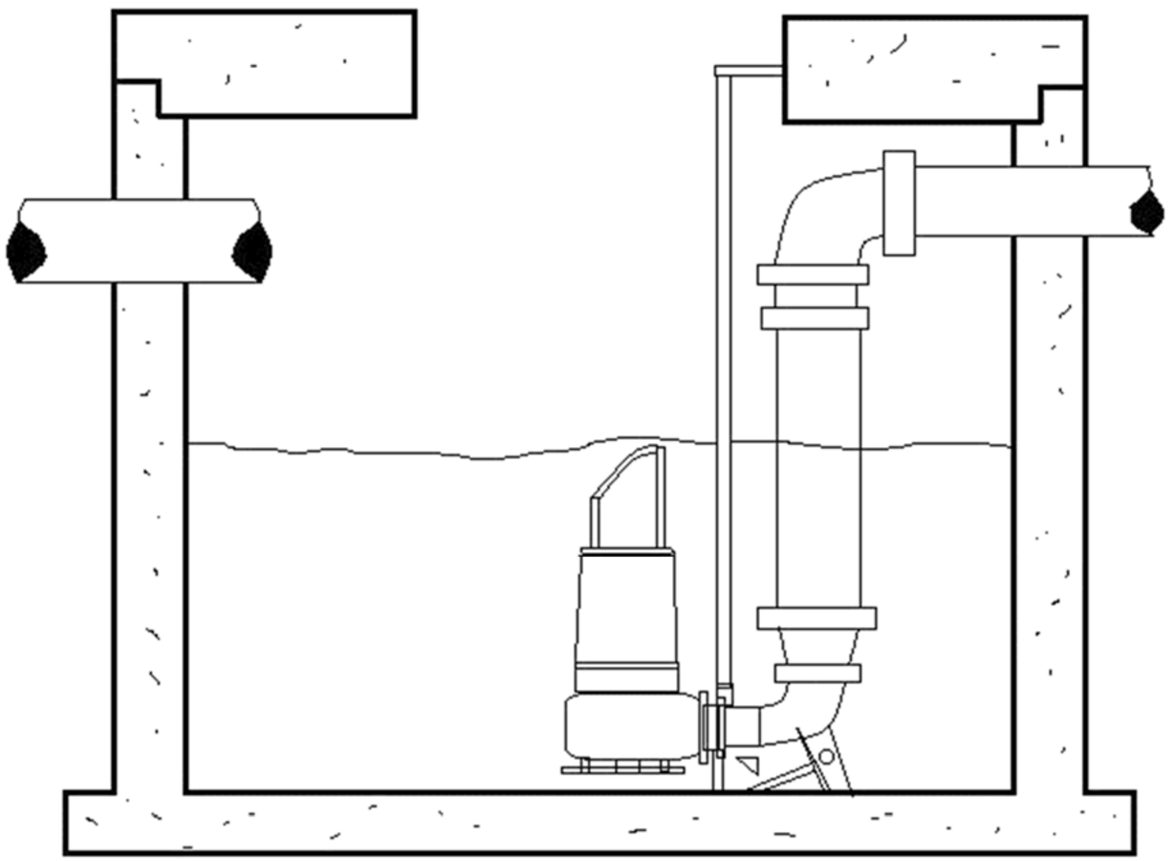
DIVIDE gal./day BY 1,000,000 TO GET MGD

10,080 / 1,000,000 = 0.010 MGD

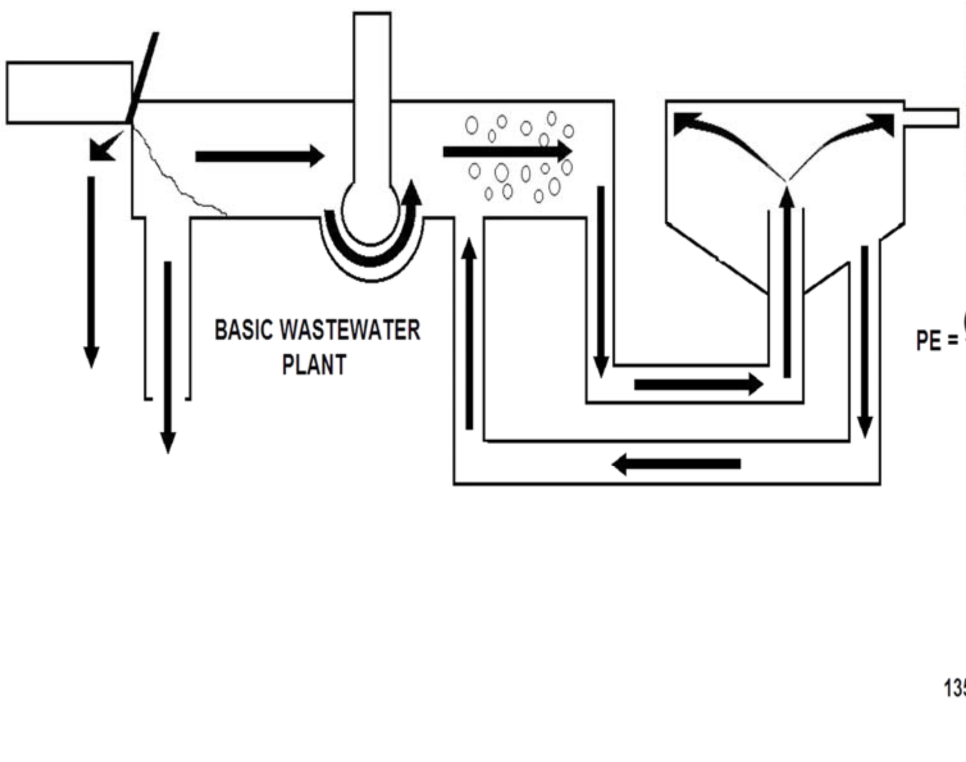
(0.010 MGD) (15 mg/L) (8.34 lbs./gal.) ($0.15/lb.) (365 days/year)= $68.49

$ 68.49 ANNUAL COST

C6. A wet well measures 12 feet by 15 feet and 11 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).



D6. A sewage treatment plant has a flow of 1.3 MGD and a BOD of 25 mg/L. On the basis of a national average of 0.2 lbs BOD per capita per day, what is the approximate population equivalent of the plant?



A SEWAGE TREATMENT PLANT HAS A FLOW OF 1.3 MGD AND A BOD OF 25 mg/L. ON THE BASIS OFA NATIONAL AVERAGE OF 0.2 lbs. BOD PER CAPITA PER DAY, WHAT IS THE APPROXIMATE POPULATION EQUIVALENT OF THE PLANT?

$$PE = \frac{(\text{FLOW/MGD})\ (\text{BOD mg/L})\ (8.34)}{\text{lbs. day/per person}}$$

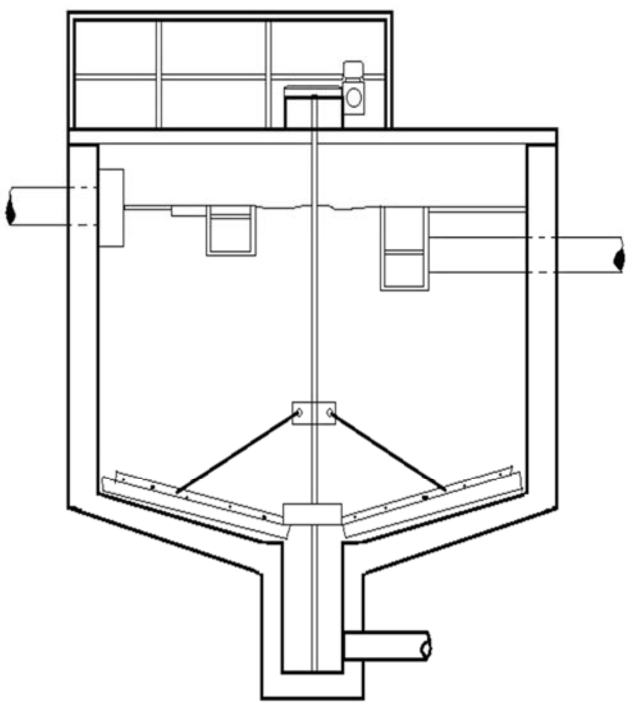
$$\frac{(1.3\ /\text{MGD})\ (25\ \text{mg/L})\ (8.34)}{0.2\ \text{lbs. day/per person}}$$

$$\frac{271.5}{0.2} = 1355.25$$

1355.25 Population Equivalent

E6. What is the detention time of a clarifier with a 750,000 gallon capacity if it receives a flow of 10.0 MGD?

DT= Volume in Gallons X 24 Divided by MGD



WHAT IS THE DETENTION TIME OF A CLARIFIER WITH A 750,000 GALLON CAPACITY IF IT RECEIVES A FLOW OF 10.0 MGD.

DT = VOLUME IN GALLONS X 24 DIVIDED BY MDG

CONVERT GALLONS TO MG/DAY. BY DIVIDING BY 1,000,000.

750,000 gal. / 1,000,000 = .75 MGD.

.75 MGD X 24 hrs./day divided BY 10.0 MGD = 1.8

DT = 1.8 hours.

Metric Math Practice Section

The metric system is known for its simplicity. All units of measurement in the metric system are based on decimals—that is, units that increase or decrease by multiples of ten. A series of Greek decimal prefixes is used to express units of ten or greater; a similar series of Latin decimal prefixes is used to express fractions. For example, deca equals ten, hecto equals one hundred, kilo equals one thousand, mega equals one million, giga equals one billion, and tera equals one trillion.

For units below one, deci equals one-tenth, centi equals one-hundredth, milli equals one-thousandth, micro equals one-millionth, nano equals one-billionth, and pico equals one-trillionth.

1 ppm = 1 pound per million pounds / or

120,000 Gallons of Water = 1,000,000 pounds

1 ppm = 1 pound per 120,000 Gallons of Water

Milligrams Per liter

(Parts Per Million)

1 Gram (weight) = 1,000 milligrams (and)

1 Liter of Water Weighs 1,000 GRAMS (so)

1 Liter of Water = 1,000,000 milligrams (1,000 X 1,000) (so)

1 Milligram in one Liter of Water = 1 milligram per liter (or)

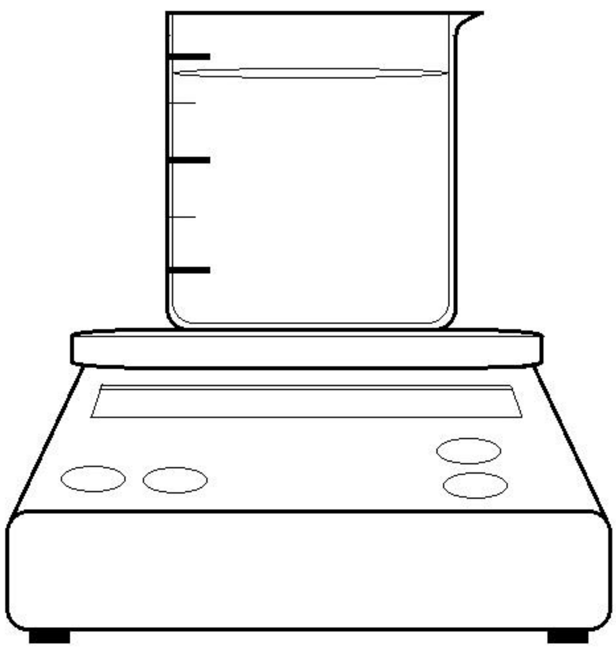
One Part in a Million Parts

Milligrams Per Liter

(Refers to a Weight Ratio)

26. How many grams equal 4,500 mg?
Metric conversions are found after the table of contents, in the front of the book.

Just simply divide by 1,000.



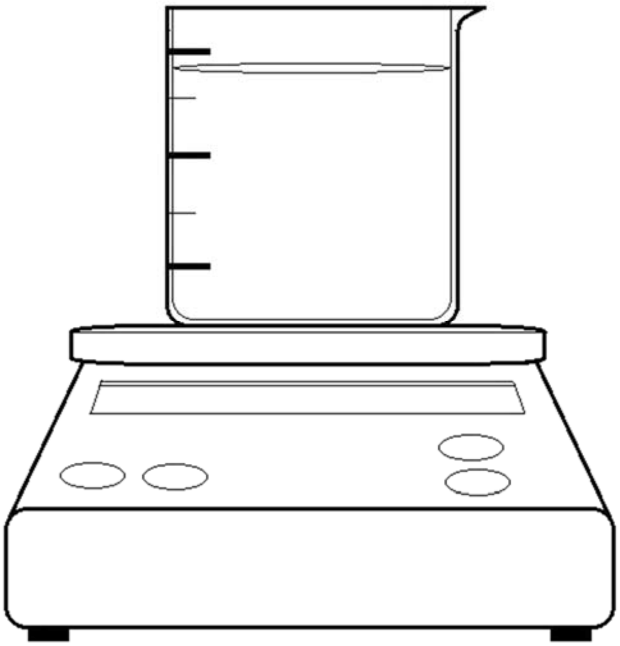
HOW MANY GRAM EQUAL 4,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

$$\frac{4500}{1000} = \quad \text{Grams}$$

Practice Questions

A7. How many grams equal 7,500 mg?

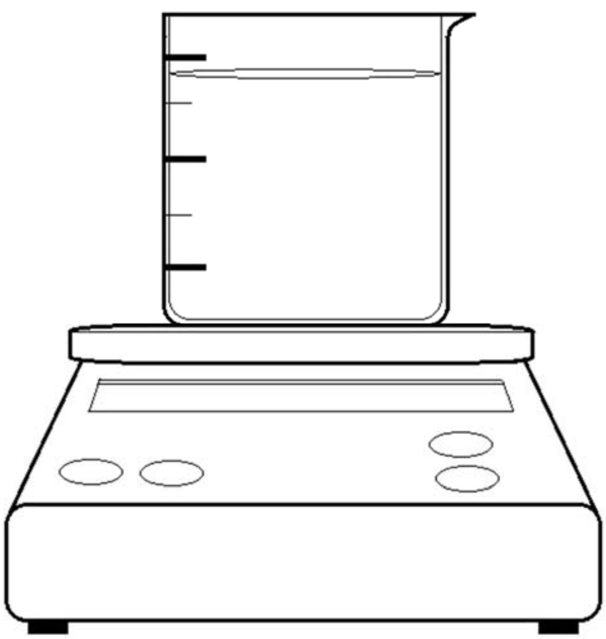


HOW MANY GRAM EQUAL 7,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

$$\frac{7500}{1000} = 7.5 \text{ Grams}$$

B7. How many grams equal 12,500 mg?



HOW MANY GRAM EQUAL 12,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

$$\frac{12500}{1000} = 12.5 \text{ Grams}$$

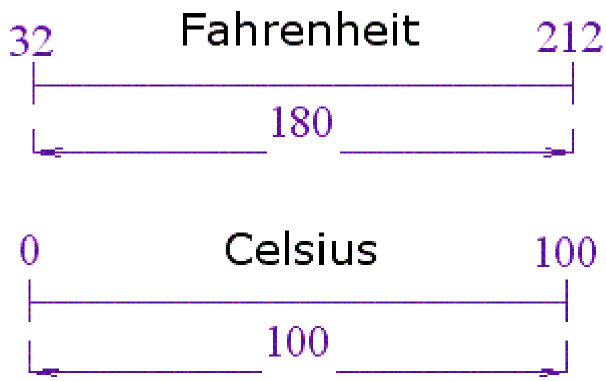
Temperature Exercise

Metric conversions are found after the table of contents, in the front of the book.

There are two main temperature scales. The Fahrenheit Scale (used in the US), and the Celsius Scale (part of the Metric System, used in most other Countries)

They both measure the same thing (temperature!), just using different numbers.

If you freeze water, it measures 0° in Celsius, but 32° in Fahrenheit
If you boil water, it measures 100° in Celsius, but 212° in Fahrenheit
The difference between freezing and boiling is 100° in Celsius, but 180° in Fahrenheit.



Conversion Method
Looking at the diagram, notice:

The scales start at a different number (32 vs. 0), so we will need to add or subtract 32
The scales rise at a different rate (180 vs. 100), so we will also need to multiply
And this is how it works out:

To convert from Celsius to Fahrenheit, first multiply by 180/100, then add 32

To convert from Fahrenheit to Celsius, first subtract 32, then multiply by 100/180

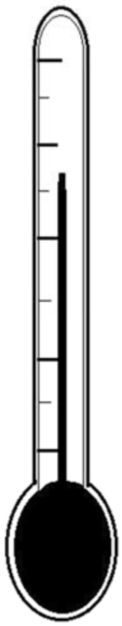
Note: 180/100 can be simplified to 9/5, and likewise 100/180=5/9.

^{0}F = (0C X 9/5) + 32   9/5 =1.8

^{0}C = (0F - 32) X 5/9   5/9 = .555

27. Convert 20 degrees Celsius to degrees Fahrenheit.

$$20^{\circ} \times 1.8 + 32 = F$$



CONVERT 20 degrees CELSIUS TO degrees FAHRENHEIT

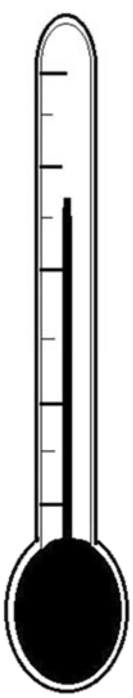
To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

(20) (1.8) + 32 = 68

20°C =

28. Convert 4 degrees Celsius to degrees Fahrenheit.

$$4^{\circ} \times 1.8 + 32 = F$$



CONVERT 4 degrees CELSIUS TO degrees FAHRENHEIT

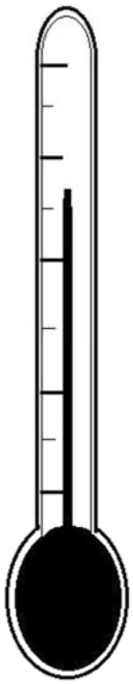
To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

(4) (1.8) + 32 = 39.2

4°C =

Practice Questions

A8. Convert 22 degrees Celsius to degrees Fahrenheit.



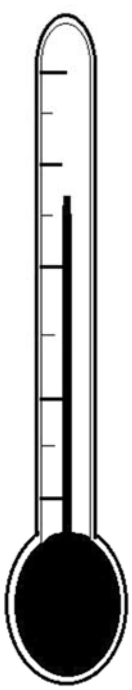
CONVERT 22 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$(22)\ (1.8) + 32 = 71.6$

$22^{\circ}C = 71.6^{\circ}F$

B8. Convert 2 degrees Celsius to degrees Fahrenheit.



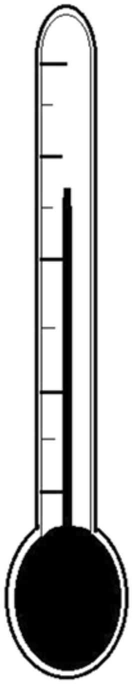
CONVERT 2 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$(2)\ (1.8) + 32 = 35.6$

$2^{\circ}C = 35.6^{\circ}F$

C8. Convert 82 degrees Fahrenheit to degrees Celsius.



CONVERT 82 degrees FAHRENHEIT TO degrees CELSIUS

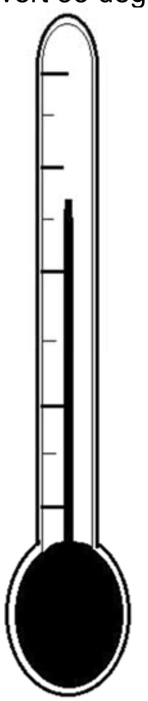
To convert Fahrenheit to Celsius :

First subtract by 32 then multiply by .555

82 - 32 (.555) = 27.75

82°F = 27.75°C

D8. Convert 33 degrees Fahrenheit to degrees Celsius.



CONVERT 33 degrees FAHRENHEIT TO degrees CELSIUS

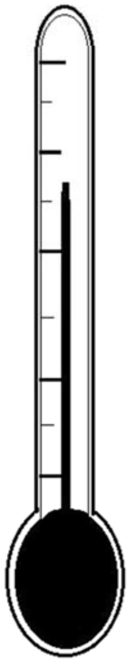
To convert Fahrenheit to Calsius :

First subtract by 32 then multiply by .555

33 - 32 (.555) = .555

33°F = .555°C

E8. Convert 72 degrees Fahrenheit to degrees Celsius.



CONVERT 72 degrees FAHRENHEIT TO degrees CELCIUS

To convert Fahrenheit to Celcius:

First subtract by 32 then multiply by .555

72 - 32 (.555) = 22.2

72°F = 22.2°C

Chemical Feed Formulas

The **chemical feed formulas** indicate how many gallons or pounds of chemical are added to a treatment system.

Dry chemical feed means you are adding a dry chemical product directly into the plant flow. The dry feed formula is a variation of the loading formula:
Dry Feed Rate, lbs/day = (Flow, MGD) x (Dose, mg/L) x (8.34 lbs/gal)

Liquid chemical feed calculations require additional steps and information. The liquid feed formula is a two-step variation of the dry feed formula:

Step 1: Dry Feed Rate, gal/day = (Flow, MGD) x (Dose, mg/L) x (8.34 lbs/gal)

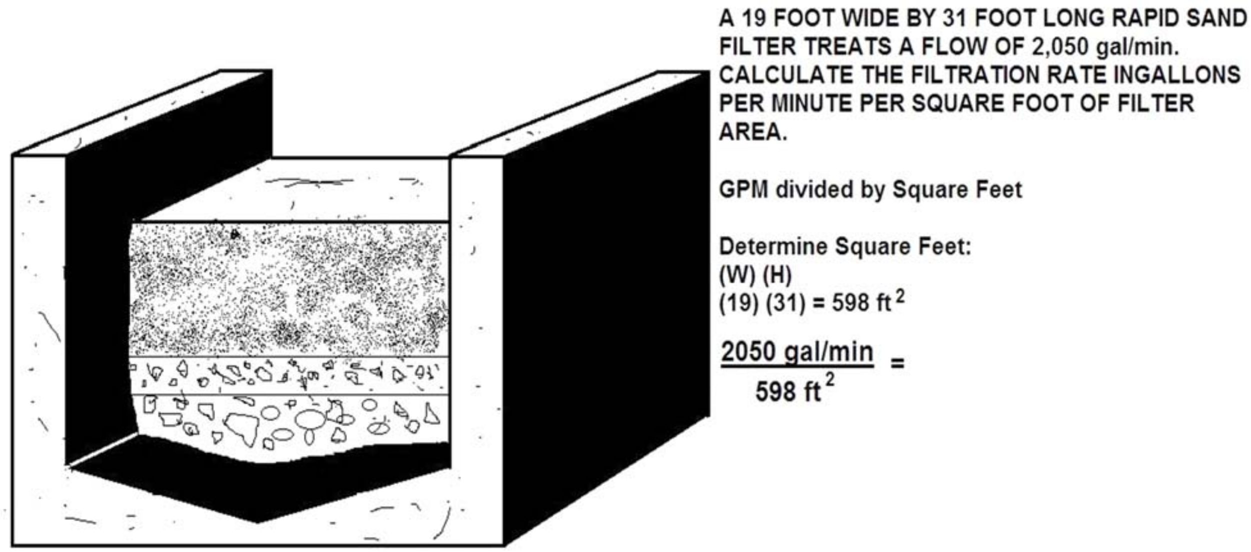
Step 2: Liquid Feed Rate, gal/day = (Dry Feed Rate, lbs/day) ÷ (Active Strength, lbs/gal)
Special Considerations – Often times, you will not be using chemicals that are full strength and/or the specific gravity of a chemical will be given instead of the active strength, in which case the following formula can be used to calculate the active strength:

Active Strength, lbs/gal = (specific gravity of the chemical) x (8.34 lbs/gal-density of water) x (% Strength of the solution ÷ 100)

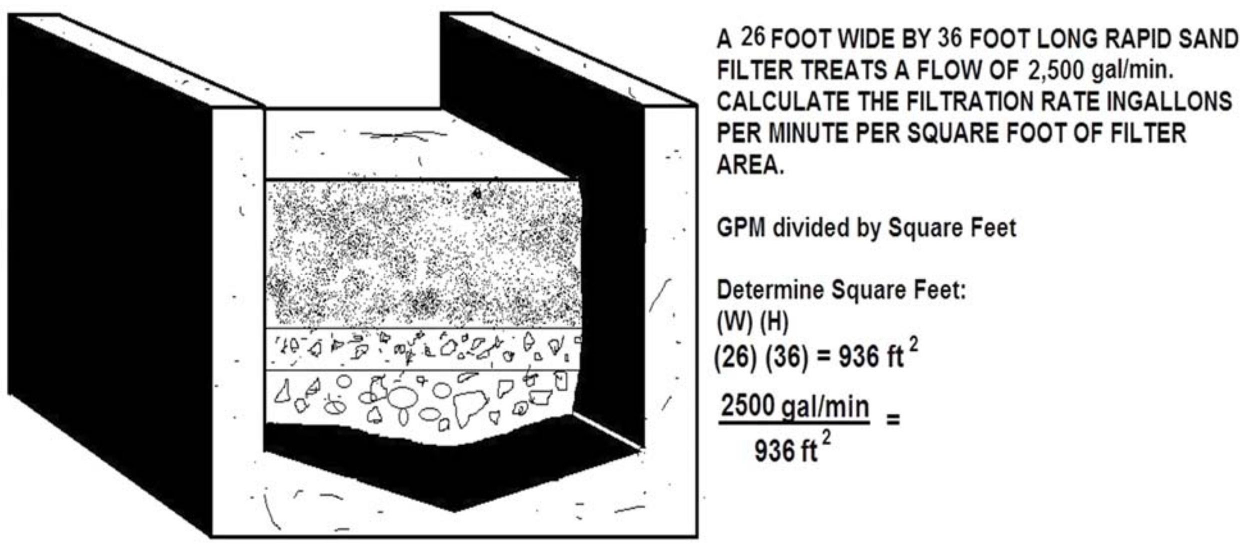
Water Treatment Filters Exercise

29. A 19 foot wide by 31 foot long rapid sand filter treats a flow of 2,050 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

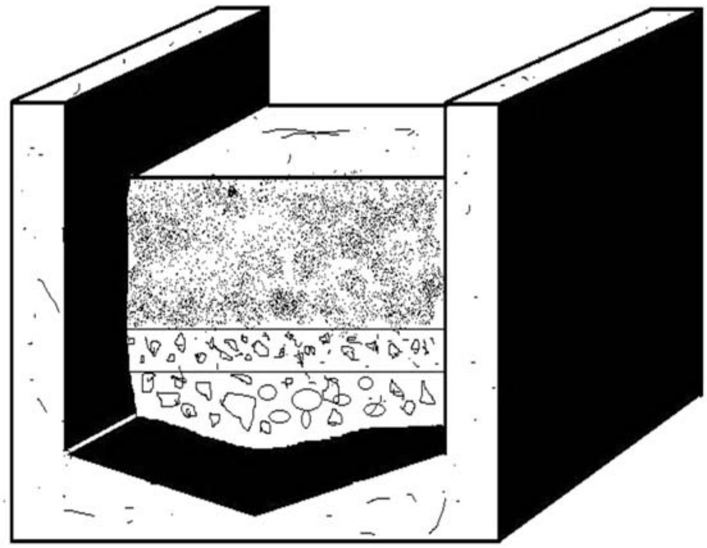
GPM ÷ Square Feet



30. A 26 foot wide by 36 foot wide long rapid sand filter treats a flow of 2,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A9. A 25 foot wide by 25 foot long rapid sand filter treats a flow of 300 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A 25 FOOT WIDE BY 25 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 300 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

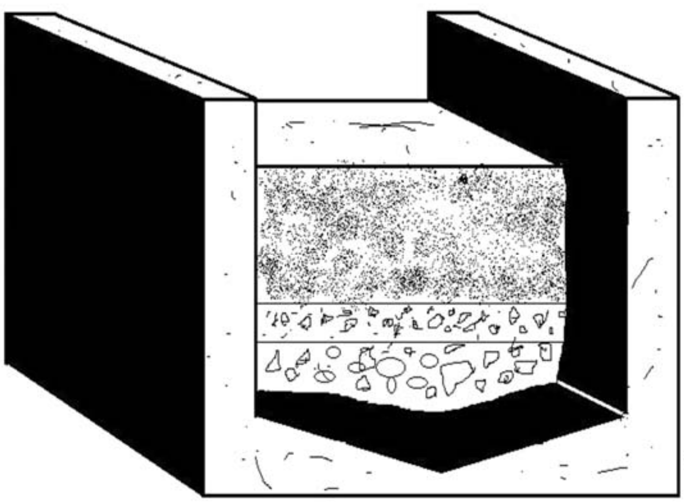
GPM divided by Square Feet

Determine Square Feet:
(W) (H)

$(25)\ (25) = 625\ ft^2$

$$\frac{300\ gal/min}{625\ ft^2} = .48\ gal/min./ft^2$$

B9. A 30 foot wide by 30 foot wide long rapid sand filter treats a flow of 1,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A 30 FOOT WIDE BY 30 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 1,500 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:
(W) (H)

$(30)\ (30) = 900\ ft^2$

$$\frac{1500\ gal/min}{900\ ft^2} = 1.67\ gal/min./ft^2$$

Chlorine Dose Review

$$\text{DOSE, mg/L} = \frac{(332)\ \text{lbs. / day}}{(5.27)\ \text{MGD} \times 8.34\ \text{lbs./mg/L/MG}}$$

$$\text{DOSE, mg/L} = (7.6)\ \text{mg/L}$$

DOSE CALCULATION EXAMPLE

Chlorine Residual Formula

Dose, mg / L = Demand, mg / L + Residual, mg / L

How To Calculate Chlorine Dose

$$(\text{mg / L } Cl_2)\ (\text{MGD flow})\ (8.34\ \text{lbs. / gal.}) = \text{lbs. / day } Cl_2$$

Formula To Convert : mg/L TO lbs./day

Chemical Dose Exercise

31. A pond has a surface area of 51,500 square feet and the desired dose of a chemical is 6.5 lbs per acre. How many pounds of the chemical will be needed?

43,560 Square feet in an acre

51,500 ÷ 43,560 = _______ X 6.5 =

32. A pond having a volume of 6.85 acre feet equals how many millions of gallons?

Practice Questions, no answers provided

A10. A pond has a surface area of 75,000 square feet and the desired dose of a chemical is 5.5 lbs per acre. How many pounds of the chemical will be needed?

B10. A pond having a volume of 13,000 acre feet equals how many millions of gallons?

33. Alum is added in a treatment plant process at a concentration of 10.5 mg/L. What should the setting on the feeder be in pounds per day if the plant is treating 3.5 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

$$GPD = \frac{GALLONS}{MINUTE} \times \frac{60\ MINUTES}{HOUR} \times \frac{24\ HOURS}{DAY}$$

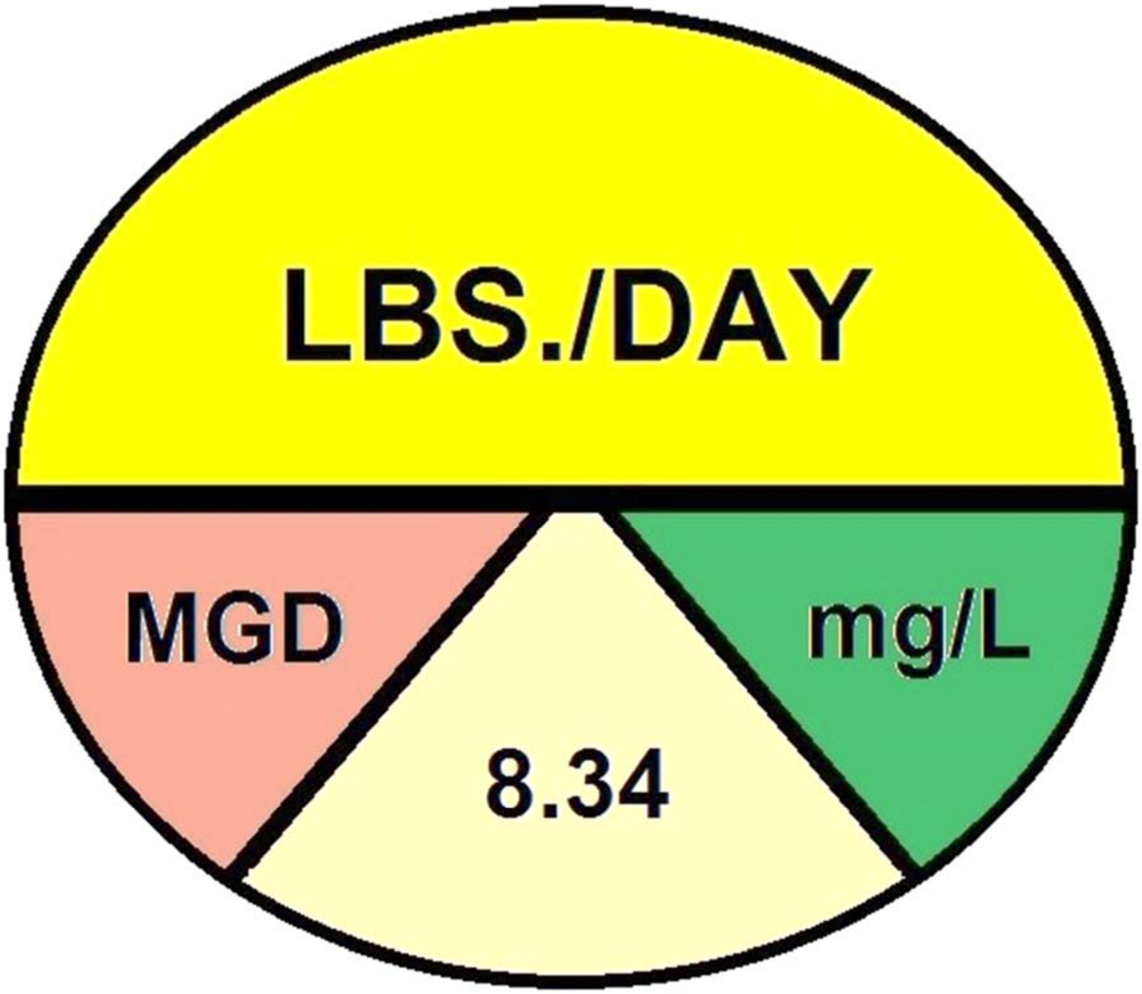
$$GT = \frac{CHLORINE\ \%\ \times 10{,}000}{1\ PPM}$$

$$\frac{GPD}{GT} = GALLONS\ OF\ CHLORINE\ PER\ 24\ HOURS$$

GPD= Gallon Per Day
GT= Gallons Treated

$$(mg\ /\ L\ Cl_2)\ (MGD\ flow)\ (8.34\ lbs.\ /\ gal.) = lbs.\ /\ day\ Cl_2$$

Formula To Convert : mg/L TO lbs./day



POUNDS FORMULA WHEEL

Practice Questions, no answers provided

A11. Alum is added in a treatment plant process at a concentration of 4.5 mg/L. What should the setting on the feeder be in pounds per day if the plant is treating 23.5 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

The Application of Formulas in a Treatment Plant

In addition to solving area and volume calculations, operation of a water or wastewater facility involves using mathematical computations to ensure the proper operation of various processes, such as:

- ✓ Detention times.
- ✓ Rates - chemical feed, loading, and flow.
- ✓ Preparation of reports.

Loading Formula
The **loading formula** is used to evaluate how much of a particular substance is being applied to a treatment unit during a specific time period. It is a general formula that can be modified to address a variety of processes including but not limited to aerator loading and applied solids.

The formula is:

Loading, lbs/day = (Flow, MGD) x (Concentration, mg/L) x (8.34 lbs/gal)

- ✓ One gallon of water weighs 8.34 lbs.
- ✓ Flow must always be in million gallons per day (MGD) for the above formula.

Q=AV Exercise Review

34. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the GPM flow rate through the pipe?
Q = 1.18 CFS x 60 Seconds x 7.48 GAL/CU.FT = 532 GPM
A = .785 X .667 X .667 X 1 = .349 Sq. Ft.
V= 3.4 Feet per second

35. A 6 inch diameter pipe delivers 280 GPM. What is the velocity of flow in the pipe in Ft/Sec?
280 GPM ÷ 60 seconds in a minute ÷ 7.48 gallons in a cu.ft. = .623 CFS

Q = .623
A = .785 X.5 X .5 =.196 Sq. Ft.
V = 3.17 Ft/Second

Practice Questions, no answers provided

A12. An 36 inch diameter pipe has water flowing at a velocity of 1.4 fps. What is the GPM flow rate through the pipe?

B12. An 18 inch diameter pipe delivers 80 GPM. What is the velocity of flow in the pipe in Ft/Sec?

Collection Math Exercise Section

36. A 24-inch sewer carries an average daily flow of 5 MGD. If the average daily flow per person from the area served is 110 GPCD (gallons per capita per day), approximately how many people discharge into the wastewater collection system?

5,000,000 divided by 110 =

37. Using a dose rate of 5 mg/L, how many pounds of chlorine per day should be used if the flow rate is 1.2 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

38. What capacity blower will be required to ventilate a manhole which is 3.5 feet in diameter and 17 feet deep? The air exchange rate is 16 air changes per hour.
.785 X 3.5' X 3.5' X 17' X 16 = ____________ CFH

39. Approximately how many feet of drop are in 455 feet of 8-inch sewer with a 0.0475 ft/ft. slope?

$$SLOPE = \frac{Rise\ (ft)}{Run\ (ft)} \qquad SLOPE\ (\%) = \frac{Rise\ (ft)}{Run\ (ft)} \times 100$$

455' X 0.0475 =

40. How much brake horsepower is required to meet the following conditions: 250 gpm, total head = 110 feet? The submersible pump that is being specified is a combined 64% efficient?

(250 X 110) ÷ (3960 X .64)

41. How wide is a trench at ground surface if a sewer trench is 2 feet wide at the bottom, 10 feet deep, and the sides have been sloped at a 4/5 horizontal to 1 vertical (3/4:1) ratio?

(3/4:1) or 3 ÷ 4 = .75 X every foot of depth

Practice Questions, no answers provided

A13. A 24-inch sewer carries an average daily flow of 3 MGD. If the average daily flow per person from the area served is 125 GPCD (gallons per capita per day), approximately how many people discharge into the wastewater collection system?

B13. Using a dose rate of 4 mg/L, how many pounds of chlorine per day should be used if the flow rate is 3.2 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

C13. What capacity blower will be required to ventilate a manhole which is 3.0 feet in diameter and 18 feet deep? The air exchange rate is 16 air changes per hour.

D13. Approximately how many feet of drop are in 575 feet of 8-inch sewer with a 0.0375 ft/ft. slope?

E13. How much brake horsepower is required to meet the following conditions: 50 gpm, total head = 110 feet? The submersible pump that is being specified is a combined 58% efficient?

F13. How wide is a trench at ground surface if a sewer trench is 2 feet wide at the bottom, 12 feet deep, and the sides have been sloped at a 4/5 horizontal to 1 vertical (3/4:1) ratio?

42. A float arrives in a manhole 550 feet down stream three minutes and thirty seconds from its release point. What is the velocity in ft/sec.?
Velocity ft/sec = distance ÷ time
550' ÷ 3 min stop convert min to sec. 3 X 60 = 180 + 30 = 210 sec
550' ÷ 210 sec = ______ fps

43. A new sewer line plan calls out a 0.6% slope of the line. An elevation reading of 108.8 feet at the manhole discharge and an elevation of 106.2 feet at a distance of 200 feet from the manhole are recorded. What is the existing slope of the line that has been installed?

$$\text{SLOPE} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \qquad \text{SLOPE (\%)} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \times 100$$

44. A triangular pile of spoil is 12 feet high and 12 feet wide at the base. The pile is 60' long. If the dump truck hauls 9 cubic yards of dirt, how many truck loads will it take to remove all of the spoil?

Given the base and the height of a triangle, we can find the area. Given the area and either the base or the height of a triangle, we can find the other dimension. The formula for area of a triangle is:

$A = \frac{1}{2} \cdot b \cdot h$ Or $A = \frac{b \cdot h}{2}$ where b is the base, h is the height.

12' X 12' ÷ 2 X 60' = _________ cu.ft (27cuft/cuyrd)

45. A red dye is poured into an upstream manhole connected to a 12 inch sewer. The dye first appears in a manhole 400 feet downstream 3 minutes later. After 3 minutes and 40 seconds the dye disappears. Estimate the flow velocity in feet per second.

Velocity ft/sec = distance ÷ time

Make sure and convert time and average it.

46. Calculate the total dosage in pounds of a chemical. Assume the sewer is completely filled with the concentration. Pipe diameter: 18 inches, Pipe length: 420 feet, Dose: 120 mg/L.

Figure out the volume first.

.785 X 1.5' X 1.5' X 420' X 7.48 =___________ convert to MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

Practice Questions, no answers provided

A14. A float arrives in a manhole 850 feet down stream four minutes and thirty seconds from its release point. What is the velocity in ft/sec.?
Velocity ft/sec = distance ÷ time

B15. A new sewer line plan calls out a 0.6% slope of the line. An elevation reading of 210.3 feet at the manhole discharge and an elevation of 106.2 feet at a distance of 100 feet from the manhole are recorded. What is the existing slope of the line that has been installed?

$$\text{SLOPE} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \qquad \text{SLOPE (\%)} = \frac{\text{Rise (ft)}}{\text{Run (ft)}} \times 100$$

C15. A triangular pile of spoil is 15 feet high and 25 feet wide at the base. The pile is 40' long. If the dump truck hauls 9 cubic yards of dirt, how many truck loads will it take to remove all of the spoil?

Given the base and the height of a triangle, we can find the area. Given the area and either the base or the height of a triangle, we can find the other dimension. The formula for area of a triangle is:

$A = \frac{1}{2} \cdot b \cdot h$ Or $A = \frac{b \cdot h}{2}$ where b is the base, h is the height.

D15. A red dye is poured into an upstream manhole connected to a 12 inch sewer. The dye first appears in a manhole 300 feet downstream 3 minutes later. After 3 minutes and 20 seconds the dye disappears. Estimate the flow velocity in feet per second.

Velocity ft/sec = distance ÷ time

Make sure and convert time and average it.

E15. Calculate the total dosage in pounds of a chemical. Assume the sewer is completely filled with the concentration. Pipe diameter: 24 inches, Pipe length: 500 feet, Dose: 20 mg/L.

Short Math Answers

1. 46750
2. 800 ÷ 8.34 = 95.92 gallons
3. 1372320 or 1.3 MGD
4. 610 X 1441 = 878400 or 0.87 MGD
5. 550 ÷ 60 = 9.167 gpm
6. 9.167 X 3.785 = 34.697 Liters
7. 630 Area 4712.4 gallons
8. 18,750 cu. ft. X 7.48 = 140250 gallons
9. 177182.5
10. 10 feet deep
11. 528462 or .5 MG
12. 1.166 Gallons X 3.785 = 4.4131 Liters
13. 15 cfs
14. 11.5 cfs
15. 5.4
16. .58875 or .6 cfs
17. 534.7 or 533 gpm
18. 3.115 or 3.2 ft/sec
19. 46.9 gal
20. .02 kg
21. 94.9 lbs/day
22. $950.12
23. .388 or .39 MGD
24. 6567.75
25. 2 hrs
26. 4.5 grams
27. 68° F
28. 39.2°F
29. 3.43 gpm/sq.ft.
30. 2.67 gpm/sq.ft.
31. 7.68 lbs
32. 2.231 MG
33. 306.495
34. 532 gpm
35. 3.2 fps
36. 45454.5 people
37. 50.04 lbs
38. 2615.6 cfh
39. 21.61 ft
40. 10.85 bhp
41. 17 ft
42. 2.62 fps
43. .013 or 1.3%
44. 17.7 or 18 trucks
45. 2 fps
46. 5.55 lbs

Glossary

A

Absolute Pressure: The pressure above zone absolute, i.e. the sum of atmospheric and gauge pressure. In vacuum related work it is usually expressed in millimeters of mercury. (mmHg).

Aerodynamics: The study of the flow of gases. The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law.

Aeronautics: The mathematics and mechanics of flying objects, in particular airplanes.

Air Break: A physical separation which may be a low inlet into the indirect waste receptor from the fixture, or device that is indirectly connected. You will most likely find an air break on waste fixtures or on non-potable lines. You should never allow an air break on an ice machine.

Air Gap Separation: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

Altitude-Control Valve: If an overflow occurs on a storage tank, the operator should first check the altitude-control valve. Altitude-Control Valve is designed to, 1. Prevent overflows from the storage tank or reservoir, or 2. Maintain a constant water level as long as water pressure in the distribution system is adequate.

Angular Motion Formulas: Angular velocity can be expressed as (angular velocity = constant):

$\omega = \theta / t$ *(2a)*

where
ω *= angular velocity (rad/s)*
θ *= angular displacement (rad)*
t *= time (s)*

Angular velocity can be expressed as (angular acceleration = constant):
$\omega = \omega_o + \alpha t$ *(2b)*

where
ω_o *= angular velocity at time zero (rad/s)*
α *= angular acceleration (rad/s²)*

Angular displacement can be expressed as (angular acceleration = constant):
$\theta = \omega_o t + 1/2 \alpha t^2$ *(2c)*

Combining 2a and 2c:
$\omega = (\omega_o^2 + 2 \alpha \theta)^{1/2}$

Angular acceleration can be expressed as:
$\alpha = d\omega / dt = d^2\theta / dt^2$ *(2d)*

where
$d\theta$ *= change of angular displacement (rad)*
dt *= change in time (s)*

Atmospheric Pressure: Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

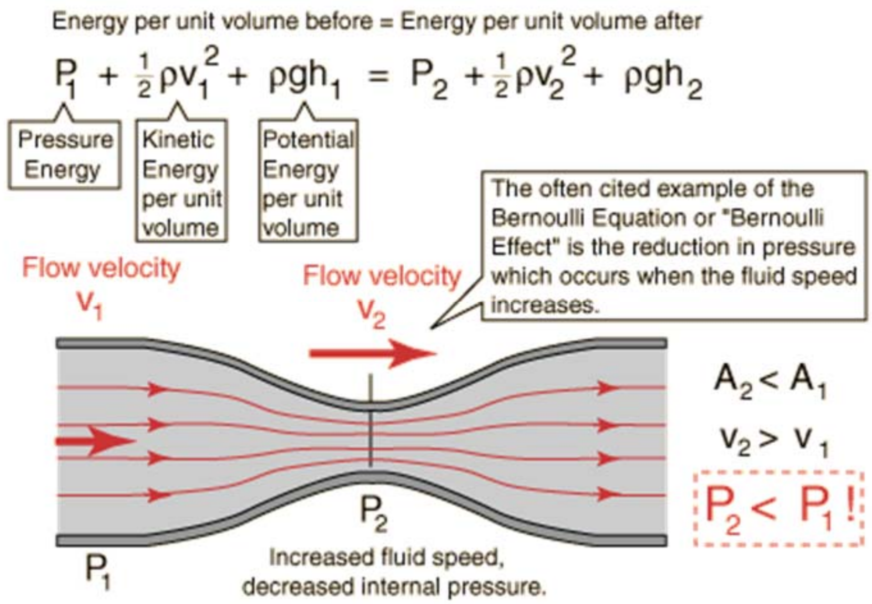
B

Backflow Prevention: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. See Cross-connection control.

Backflow: To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect.

Backsiphonage: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point. Is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is "sucked" into the system because the main is under a vacuum.

Bernoulli's Equation: Describes the behavior of moving fluids along a streamline. The Bernoulli Equation can be considered to be a statement of the conservation of energy principle appropriate for flowing fluids. The qualitative behavior that is usually labeled with the term "***Bernoulli effect***" is the lowering of fluid pressure in regions where the flow velocity is increased. This lowering of pressure in a constriction of a flow path may seem counterintuitive, but seems less so when you consider pressure to be energy density. In the high velocity flow through the constriction, kinetic energy must increase at the expense of pressure energy.



A special form of the Euler's equation derived along a fluid flow streamline is often called the **Bernoulli Equation.**

$$\frac{\partial}{\partial s}\left(\frac{v^2}{2}+\frac{p}{\rho}+g\cdot h\right)=0 \qquad (1)$$

where

v = flow speed

p = pressure

ρ = density

g = gravity

h = height

$$\frac{v^2}{2}+\frac{p}{\rho}+g\cdot h=\text{Constant} \qquad (2)$$

$$\frac{v^2}{2\cdot g}+\frac{p}{\gamma}+h=\text{Constant} \qquad (3)$$

where

$\gamma=\rho\cdot g$

$$\frac{\rho\cdot v^2}{2}+p=\text{Constant} \qquad (4)$$

$$\frac{\rho\cdot v^2}{2}=p_d \qquad (5)$$

$$\frac{\rho\cdot v_1^2}{2}+p_1=\frac{\rho\cdot v_2^2}{2}+p_2=\text{Constant} \qquad (6)$$

For steady state incompressible flow the Euler equation becomes (1). If we integrate (1) along the streamline it becomes (2). (2) can further be modified to (3) by dividing by gravity.

Head of Flow: Equation (3) is often referred to as the **head** because all elements have the unit of length.

Bernoulli's Equation Continued:

Dynamic Pressure

(2) and (3) are two forms of the Bernoulli Equation for steady state incompressible flow. If we assume that the gravitational body force is negligible, (3) can be written as (4). Both elements in the equation have the unit of pressure and it's common to refer the flow velocity component as the **dynamic pressure** of the fluid flow (5).

Since energy is conserved along the streamline, (4) can be expressed as (6). Using the equation we see that increasing the velocity of the flow will reduce the pressure, decreasing the velocity will increase the pressure.

This phenomena can be observed in a **venturi meter** where the pressure is reduced in the constriction area and regained after. It can also be observed in a **pitot tube** where the **stagnation** pressure is measured. The stagnation pressure is where the velocity component is zero.

Bernoulli's Equation Continued:

Pressurized Tank

If the tanks are pressurized so that product of gravity and height (g h) is much less than the pressure difference divided by the density, (e4) can be transformed to (e6).
The velocity out from the tanks depends mostly on the pressure difference.

Example - outlet velocity from a pressurized tank

The outlet velocity of a pressurized tank where

$p_1 = 0.2\ MN/m^2,\ p_2 = 0.1\ MN/m^2\ A_2/A_1 = 0.01,\ h = 10\ m$

can be calculated as

$V_2 = [(2/(1-(0.01)^2)\ (\ (0.2 - 0.1)x10^6\ /1x10^3 + 9.81\ x\ 10)]^{1/2} = \underline{19.9\ m/s}$

Coefficient of Discharge - Friction Coefficient

Due to friction the real velocity will be somewhat lower than this theoretical example. If we introduce a **friction coefficient** *c* (coefficient of discharge), (e5) can be expressed as (e5b). The coefficient of discharge can be determined experimentally. For a sharp edged opening it may be as low as 0.6. For smooth orifices it may be between 0.95 and 1.

Bingham Plastic Fluids: Bingham Plastic Fluids have a yield value which must be exceeded before it will start to flow like a fluid. From that point the viscosity will decrease with increase of agitation. Toothpaste, mayonnaise and tomato catsup are examples of such products.

Boundary Layer: The layer of fluid in the immediate vicinity of a bounding surface.

Bulk Modulus and Fluid Elasticity: An introduction to and a definition of the Bulk Modulus Elasticity commonly used to characterize the compressibility of fluids.

The Bulk Modulus Elasticity can be expressed as

$E = - dp / (dV / V)$ *(1)*

where
E *= bulk modulus elasticity*
dp *= differential change in pressure on the object*
dV *= differential change in volume of the object*
V *= initial volume of the object*

The Bulk Modulus Elasticity can be alternatively expressed as

$E = - dp / (d\rho / \rho)$ *(2)*

where
$d\rho$ *= differential change in density of the object*
ρ *= initial density of the object*

An increase in the pressure will decrease the volume (1). A decrease in the volume will increase the density (2).

- The SI unit of the bulk modulus elasticity is N/m^2 (Pa)
- The imperial (BG) unit is lb_f/in^2 (psi)
- 1 lb_f/in^2 (psi) = 6.894 10^3 N/m^2 (Pa)

A large Bulk Modulus indicates a relatively incompressible fluid.

Bulk Modulus for some common fluids can be found in the table below:

Bulk Modulus - *E*	Imperial Units - BG (psi, lb_f/in^2) x 10^5	SI Units (Pa, N/m^2) x 10^9
Carbon Tetrachloride	1.91	1.31
Ethyl Alcohol	1.54	1.06
Gasoline	1.9	1.3
Glycerin	6.56	4.52
Mercury	4.14	2.85
SAE 30 Oil	2.2	1.5
Seawater	3.39	2.35
Water	3.12	2.15

C

Capillarity: (or capillary action) The ability of a narrow tube to draw a liquid upwards against the force of gravity.

The height of liquid in a tube due to capillarity can be expressed as

$h = 2\, \sigma \cos\theta / (\rho\, g\, r)$ *(1)*

where
h *= height of liquid (ft, m)*
σ *= surface tension (lb/ft, N/m)*
θ *= contact angle*
ρ *= density of liquid* (lb/ft^3, kg/m^3)
g *= acceleration due to gravity* ($32.174\ ft/s^2$, $9.81\ m/s^2$)
r *= radius of tube (ft, m)*

Cauchy Number: A dimensionless value useful for analyzing fluid flow dynamics problems where compressibility is a significant factor.
The Cauchy Number is the ratio between inertial and the compressibility force in a flow and can be expressed as

$C = \rho\, v^2 / E$ *(1)*

where
ρ *= density* (kg/m^3)
v *= flow velocity (m/s)*
E *= bulk modulus elasticity* (N/m^2)

The bulk modulus elasticity has the dimension pressure and is commonly used to characterize the compressibility of a fluid.

The Cauchy Number is the square root of the Mach Number

$M^2 = Ca$ (3)

where
C = Mach Number

Cavitation: Under the wrong condition, cavitation will reduce the components life time dramatically. Cavitation may occur when the local static pressure in a fluid reach a level below the vapor pressure of the liquid at the actual temperature. According to the Bernoulli Equation this may happen when the fluid accelerates in a control valve or around a pump impeller. The vaporization itself does not cause the damage - the damage happens when the vapor almost immediately collapses after evaporation when the velocity is decreased and pressure increased. Cavitation means that cavities are forming in the liquid that we are pumping. When these cavities form at the suction of the pump several things happen all at once: We experience a loss in capacity. We can no longer build the same head (pressure). The efficiency drops. The cavities or bubbles will collapse when they pass into the higher regions of pressure causing noise, vibration, and damage to many of the components. The cavities form for five basic reasons and it is common practice to lump all of them into the general classification of cavitation.

This is an error because we will learn that to correct each of these conditions we must understand why they occur and how to fix them. Here they are in no particular order: Vaporization, Air ingestion, Internal recirculation, Flow turbulence and finally the Vane Passing Syndrome.

Avoiding Cavitation
Cavitation can in general be avoided by:

- increasing the distance between the actual local static pressure in the fluid - and the vapor pressure of the fluid at the actual temperature

This can be done by:

- reengineering components initiating high speed velocities and low static pressures
- increasing the total or local static pressure in the system
- reducing the temperature of the fluid

Reengineering of Components Initiating High Speed Velocity and Low Static Pressure
Cavitation and damage can be avoided by using special components designed for the actual rough conditions.

- Conditions such as huge pressure drops can - with limitations - be handled by Multi Stage Control Valves
- Difficult pumping conditions - with fluid temperatures close to the vaporization temperature - can be handled with a special pump - working after another principle than the centrifugal pump.

Cavitation: Increasing the Total or Local Pressure in the System
By increasing the total or local pressure in the system, the distance between the static pressure and the vaporization pressure is increased and vaporization and cavitation may be avoided.

The ratio between static pressure and the vaporization pressure, an indication of the possibility of vaporization, is often expressed by the Cavitation Number. Unfortunately it may not always be possible to increase the total static pressure due to system classifications or other limitations. Local static pressure in the component may then be increased by lowering the component in the system. Control valves and pumps should in general be positioned in the lowest part of the system to maximize the static head. This is common for boiler feeding pumps receiving hot condensate (water close to 100 °C) from a condensate receiver.

Cavitation Continued: Reducing the Temperature of the Fluid
The vaporization pressure is highly dependent on the fluid temperature. Water, our most common fluid, is an example:

Temperature (°C)	Vapor Pressure (kN/m^2)
0	0.6
5	0.9
10	1.2
15	1.7
20	2.3
25	3.2
30	4.3
35	5.6
40	7.7
45	9.6
50	12.5
55	15.7
60	20
65	25
70	32.1
75	38.6
80	47.5
85	57.8
90	70
95	84.5
100	101.33

As we can see - the possibility of evaporation and cavitation increases dramatically with the water temperature.

Cavitation can be avoided by locating the components in the coldest part of the system. For example, it is common to locate the pumps in heating systems at the "cold" return lines. The situation is the same for control valves. Where it is possible they should be located on the cold side of heat exchangers.

Cavitations Number: A "special edition" of the dimensionless Euler Number.

The Cavitations Number is useful for analyzing fluid flow dynamics problems where cavitations may occur. The Cavitations Number can be expressed as

$Ca = (p_r - p_v) / 1/2\ \rho\ v^2$ (1)

where
Ca = Cavitations number
p_r = reference pressure (Pa)
p_v = vapor pressure of the fluid (Pa)
ρ = density of the fluid (kg/m^3)
v = velocity of fluid (m/s)

Centrifugal Pump: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

Chezy Formula: Conduits flow and mean velocity. The Chezy formula can be used to calculate mean flow velocity in conduits and is expressed as

$v = c\ (R\ S)^{1/2}$ (1)

where
v = mean velocity (m/s, ft/s)
c = the Chezy roughness and conduit coefficient
R = hydraulic radius of the conduit (m, ft)
S = slope of the conduit (m/m, ft/ft)

In general the Chezy coefficient - *c* - is a function of the flow Reynolds Number - Re - and the relative roughness - *ε/R* - of the channel.

ε is the characteristic height of the roughness elements on the channel boundary.

Coanda Effect: The tendency of a stream of fluid to stay attached to a convex surface, rather than follow a straight line in its original direction.

Colebrook Equation: The friction coefficients used to calculate pressure loss (or major loss) in ducts, tubes and pipes can be calculated with the Colebrook equation.

$1 / \lambda^{1/2} = -2 \log ((2.51 / (Re\ \lambda^{1/2})) + ((k / d_h) / 3.72))$ (1)

where
λ = D'Arcy-Weisbach friction coefficient
Re = Reynolds Number
k = roughness of duct, pipe or tube surface (m, ft)
d_h = hydraulic diameter (m, ft)

The Colebrook equation is only valid at turbulent flow conditions.

Note that the friction coefficient is involved on both sides of the equation and that the equation must be solved by iteration.

The Colebrook equation is generic and can be used to calculate the friction coefficients in different kinds of fluid flows - air ventilation ducts, pipes and tubes with water or oil, compressed air and much more.

Common Pressure Measuring Devices: The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands which changes the length of the wire attached. This change of length of the wire changes the Resistance of the wire, which is then converted to head. Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are common types of level sensors.

Compressible Flow: We know that fluids are classified as Incompressible and Compressible fluids. Incompressible fluids do not undergo significant changes in density as they flow. In general, liquids are incompressible; water being an excellent example. In contrast compressible fluids do undergo density changes.

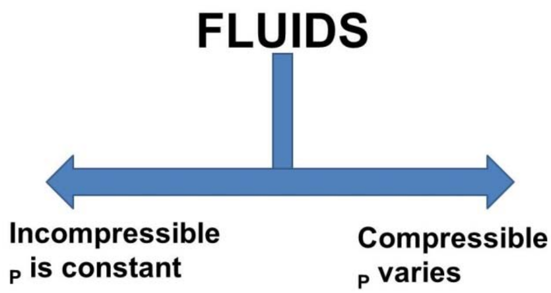
Gases are generally compressible; air being the most common compressible fluid we can find. Compressibility of gases leads to many interesting features such as shocks, which are absent for incompressible fluids. Gas dynamics is the discipline that studies the flow of compressible fluids and forms an important branch of Fluid Mechanics. In this book we give a broad introduction to the basics of compressible fluid flow.

In a compressible flow the compressibility of the fluid must be taken into account. The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of **Gas Mixtures** - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and **Universal Gas Constant** - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Compression and Expansion of Gases: If the compression or expansion takes place under constant temperature conditions - the process is called **isothermal.** The isothermal process can on the basis of the Ideal Gas Law be expressed as:

$$p / \rho = constant \quad (1)$$

where
p = absolute pressure
ρ = density



Confined Space Entry: Entry into a confined space requires that all entrants wear a harness and safety line. If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be two people outside standing by to remove the injured operator.

Conservation Laws: The conservation laws states that particular measurable properties of an isolated physical system does not change as the system evolves: Conservation of energy (including mass). Fluid Mechanics and Conservation of Mass - The law of conservation of mass states that mass can neither be created or destroyed.

Contaminant: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

Contamination: To make something bad; to pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.

Corrosion: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

Cross-Contamination: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical.

D

Darcy-Weisbach Equation: The **pressure loss** (or major loss) in a pipe, tube or duct can be expressed with the D'Arcy-Weisbach equation:

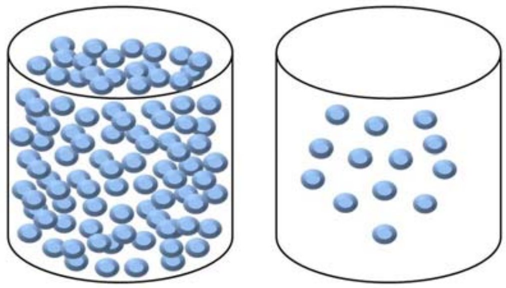
$\Delta p = \lambda \, (l / d_h) \, (\rho \, v^2 / 2)$ *(1)*

where
Δp = *pressure loss (Pa, N/m², lbf/ft²)* — $(Pa,\ N/m^2,\ lb_f/ft^2)$
λ = *D'Arcy-Weisbach friction coefficient*
l = *length of duct or pipe (m, ft)*
d_h = *hydraulic diameter (m, ft)*
ρ = *density* $(kg/m^3,\ lb/ft^3)$

Note! Be aware that there are two alternative friction coefficients present in the literature. One is 1/4 of the other and (1) must be multiplied with four to achieve the correct result. This is important to verify when selecting friction coefficients from Moody diagrams.

Density: Is a physical property of matter, as each element and compound has a unique density associated with it.

Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. For example: A rock is obviously more dense than a crumpled piece of paper of the same size. A Styrofoam cup is less dense than a ceramic cup. Density may also refer to how closely "packed" or "crowded" the material appears to be - again refer to the Styrofoam vs. ceramic cup. Take a look at the two boxes below.



Each box has the same volume. ***If each ball has the same mass, which box would weigh more? Why?***

The box that has more balls has more mass per unit of volume. This property of matter is called density. The density of a material helps to distinguish it from other materials. Since mass is usually expressed in grams and volume in cubic centimeters, density is expressed in grams/cubic centimeter. We can calculate density using the formula:

Density= Mass/Volume

The density can be expressed as

$\rho = m / V = 1 / v_g$ *(1)*

where
ρ *= density (kg/m^3)*
m *= mass (kg)*
V *= volume (m^3)*
v_g *= specific volume (m^3/kg)*

The SI units for density are kg/m^3. The imperial (BG) units are lb/ft^3 (slugs/ft^3). While people often use pounds per cubic foot as a measure of density in the U.S., pounds are really a measure of force, not mass. Slugs are the correct measure of mass. You can multiply slugs by 32.2 for a rough value in pounds. The higher the density, the tighter the particles are packed inside the substance. Density is a physical property constant at a given temperature and density can help to identify a substance.

Example - Use the Density to Identify the Material:
An unknown liquid substance has a mass of 18.5 g and occupies a volume of 23.4 ml. (milliliter).

The density can be calculated as

$$\rho = [18.5\ (g) / 1000\ (g/kg)] / [23.4\ (ml) / 1000\ (ml/l)\ 1000\ (l/m^3)\ ]$$
$$= 18.5\ 10^{-3}\ (kg) / 23.4\ 10^{-6}\ (m^3)$$
$$= \underline{790}\ kg/m^3$$

If we look up densities of some common substances, we can find that ethyl alcohol, or ethanol, has a density of <u>790</u> kg/m^3. Our unknown liquid may likely be ethyl alcohol!

Example - Use Density to Calculate the Mass of a Volume
The density of titanium is 4507 kg/m^3 . Calculate the mass of 0.17 m^3 titanium!

$$m = 0.17\ (m^3)\ 4507\ (kg/m^3)$$
$$= \underline{766.2}\ kg$$

Dilatant Fluids: Shear Thickening Fluids or Dilatant Fluids increase their viscosity with agitation. Some of these liquids can become almost solid within a pump or pipe line. With agitation, cream becomes butter and Candy compounds, clay slurries and similar heavily filled liquids do the same thing.

Drag Coefficient: Used to express the drag of an object in moving fluid. Any object moving through a fluid will experience a drag - the net force in direction of flow due to the pressure and shear stress forces on the surface of the object.

The drag force can be expressed as:

$$F_d = c_d\ 1/2\ \rho\ v^2\ A \quad (1)$$

where
F_d = *drag force (N)*
c_d = *drag coefficient*
ρ = *density of fluid*
v = *flow velocity*
A = *characteristic frontal area of the body*

The drag coefficient is a function of several parameters as shape of the body, Reynolds Number for the flow, Froude number, Mach Number and Roughness of the Surface.
The characteristic frontal area - *A* - depends on the body.

Dynamic or Absolute Viscosity: The viscosity of a fluid is an important property in the analysis of liquid behavior and fluid motion near solid boundaries. The viscosity of a fluid is its resistance to shear or flow and is a measure of the adhesive/cohesive or frictional properties of a fluid. The resistance is caused by intermolecular friction exerted when layers of fluids attempts to slide by another.

Dynamic Pressure: Dynamic pressure is the component of fluid pressure that represents a fluids kinetic energy. The dynamic pressure is a defined property of a moving flow of gas or liquid and can be expressed as

$p_d = 1/2\ \rho\ v^2$ *(1)*

where
p_d *= dynamic pressure (Pa)*
ρ *= density of fluid* (kg/m^3)
v *= velocity (m/s)*

Dynamic, Absolute and Kinematic Viscosity: The viscosity of a fluid is an important property in the analysis of liquid behavior and fluid motion near solid boundaries. The viscosity is the fluid resistance to shear or flow and is a measure of the adhesive/cohesive or frictional fluid property. The resistance is caused by intermolecular friction exerted when layers of fluids attempts to slide by another.

Viscosity is a measure of a fluid's resistance to flow.

The knowledge of viscosity is needed for proper design of required temperatures for storage, pumping or injection of fluids.

Common used units for viscosity are
- CentiPoises (cp) = CentiStokes (cSt) × Density
- SSU[1] = Centistokes (cSt) × 4.55
- Degree Engler[1] × 7.45 = Centistokes (cSt)
- Seconds Redwood[1] × 0.2469 = Centistokes (cSt)

[1]centistokes greater than 50

There are two related measures of fluid viscosity - known as **dynamic** (**or absolute**) and **kinematic** viscosity.

Dynamic (absolute) Viscosity: The tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid. The shearing stress between the layers of non-turbulent fluid moving in straight parallel lines can be defined for a Newtonian fluid as:

The dynamic or absolute viscosity can be expressed like

$\tau = \mu\ dc/dy$ *(1)*

where
τ *= shearing stress*
μ *= dynamic viscosity*

Equation (1) is known as the **Newton's Law of Friction**.

In the SI system the dynamic viscosity units are **N s/m^2**, **Pa s** or **kg/m s** where

- *1 Pa s = 1 N s/m^2 = 1 kg/m s*

The dynamic viscosity is also often expressed in the metric CGS (centimeter-gram-second) system as **g/cm.s**, **dyne.s/cm^2** or **poise (p)** where

- *1 poise = dyne s/cm^2 = g/cm s = 1/10 Pa s*

For practical use the Poise is to large and its usual divided by 100 into the smaller unit called the **centiPoise (cP)** where

- *1 p = 100 cP*

Water at 68.4^{o}F (20.2^{o}C) has an absolute viscosity of one - 1 - centiPoise.

E

Elevation Head: The energy possessed per unit weight of a fluid because of its elevation. 1 foot of water will produce .433 pounds of pressure head.

Energy: The ability to do work. Energy can exist in one of several forms, such as heat, light, mechanical, electrical, or chemical. Energy can be transferred to different forms. It also can exist in one of two states, either potential or kinetic.

Energy and Hydraulic Grade Line: The hydraulic grade and the energy line are graphical forms of the Bernoulli equation. For steady, in viscid, incompressible flow the total energy remains constant along a stream line as expressed through the Bernoulli

Equation:

$p + 1/2\ \rho\ v^2 + \gamma\ h$ = constant along a streamline (1)

where
p = static pressure (relative to the moving fluid)
ρ = density
γ = specific weight
v = flow velocity
g = acceleration of gravity
h = elevation height

Each term of this equation has the dimension *force per unit area* - psi, lb/ft^2 or N/m^2.

The Head

By dividing each term with the specific weight - $\gamma = \rho\ g$ - (1) can be transformed to express the "head":

$p / \gamma + v^2 / 2\ g + h$ = constant along a streamline = H (2)
where
H = the total head

Each term of this equation has the dimension length - ft, m.

The Total Head
(2) states that the sum of **pressure head** - *p / γ* -, **velocity head** - $v^2 / 2 g$ - and **elevation head** - *h* - is constant along the stream line. This constant can be called **the total head** - *H* -.

The total head in a flow can be measured by the stagnation pressure using a pitot tube.

Energy and Hydraulic Grade Line:
The Piezometric Head
The sum of pressure head - *p / γ* - and elevation head - *h* - is called **the piezometric head**. The piezometric head in a flow can be measured through an flat opening parallel to the flow.

Energy and Hydraulic Grade Line Continued:
The Energy Line
The Energy Line is a line that represents the total head available to the fluid and can be expressed as:

$$EL = H = p / \gamma + v^2 / 2 g + h = \text{constant along a streamline} \quad (3)$$

where
EL = Energy Line

For a fluid flow without any losses due to friction (major losses) or components (minor losses) the energy line would be at a constant level. In the practical world the energy line decreases along the flow due to the losses.

A turbine in the flow will reduce the energy line and a pump or fan will increase the energy line.

The Hydraulic Grade Line
The Hydraulic Grade Line is a line that represent the total head available to the fluid minus the velocity head and can be expressed as:

$$HGL = p / \gamma + h \quad (4)$$

where
HGL = Hydraulic Grade Line

The hydraulic grade line lies one velocity head below the energy line.

Entrance Length and Developed Flow: Fluids need some length to develop the velocity profile after entering the pipe or after passing through components such as bends, valves, pumps, and turbines or similar.

The Entrance Length: The entrance length can be expressed with the dimensionless **Entrance Length Number:**

$El = l_e / d$ (1)

where
El = Entrance Length Number
l_e = length to fully developed velocity profile
d = tube or duct diameter

The Entrance Length Number for Laminar Flow
The Entrance length number correlation with the Reynolds Number for laminar flow can be expressed as:

$El_{laminar} = 0.06\ Re$ (2)

where
Re = Reynolds Number

The Entrance Length Number for Turbulent Flow
The Entrance length number correlation with the Reynolds Number for turbulent flow can be expressed as:

$El_{turbulent} = 4.4\ Re^{1/6}$ (3)

Entropy in Compressible Gas Flow: Calculating entropy in compressible gas flow
Entropy change in compressible gas flow can be expressed as

$ds = c_v \ln(T_2 / T_1) + R \ln(\rho_1 / \rho_2)$ (1)
or
$ds = c_p \ln(T_2 / T_1) - R \ln(p_2 / p_1)$ (2)

where
ds = entropy change
c_v = specific heat capacity at a constant volume process
c_p = specific heat capacity at a constant pressure process
T = absolute temperature
R = individual gas constant
ρ = density of gas
p = absolute pressure

Equation of Continuity: The Law of Conservation of Mass states that mass can be neither created nor destroyed. Using the Mass Conservation Law on a **steady flow** process - flow where the flow rate doesn't change over time - through a control volume where the stored mass in the control volume doesn't change - implements that inflow equals outflow. This statement is called **the Equation of Continuity.** Common application where **the Equation of Continuity** can be used are pipes, tubes and ducts with flowing fluids and gases, rivers, overall processes as power plants, diaries, logistics in general, roads, computer networks and semiconductor technology and more.

The Equation of Continuity and can be expressed as:

$m = \rho_{i1} v_{i1} A_{i1} + \rho_{i2} v_{i2} A_{i2} +..+ \rho_{in} v_{in} A_{im}$

$= \rho_{o1} v_{o1} A_{o1} + \rho_{o2} v_{o2} A_{o2} +..+ \rho_{om} v_{om} A_{om}$ *(1)*

where

m = mass flow rate (kg/s)

ρ = density (kg/m^3)

v = speed (m/s)

A = area (m^2)

With uniform density equation (1) can be modified to

$q = v_{i1} A_{i1} + v_{i2} A_{i2} +..+ v_{in} A_{im}$

$= v_{o1} A_{o1} + v_{o2} A_{o2} +..+ v_{om} A_{om}$ *(2)*

where

q = flow rate (m^3/s)

$\rho_{i1} = \rho_{i2} = . . = \rho_{in} = \rho_{o1} = \rho_{o2} = . .= \rho_{om}$

Example - Equation of Continuity

10 m^3/h of water flows through a pipe of 100 mm inside diameter. The pipe is reduced to an inside dimension of 80 mm. Using equation (2) the velocity in the 100 mm pipe can be calculated as

$(10\ m^3/h)(1 / 3600\ h/s) = v_{100}\ (3.14 \times 0.1\ (m) \times 0.1\ (m) / 4)$

or

$v_{100} = (10\ m^3/h)(1 / 3600\ h/s) / (3.14 \times 0.1\ (m) \times 0.1\ (m) / 4)$

$= \underline{0.35}\ m/s$

Using equation (2) the velocity in the 80 mm pipe can be calculated

$(10\ m^3/h)(1 / 3600\ h/s) = v_{80}\ (3.14 \times 0.08\ (m) \times 0.08\ (m) / 4)$

or

$v_{100} = (10\ m^3/h)(1 / 3600\ h/s) / (3.14 \times 0.08\ (m) \times 0.08\ (m) / 4)$

$= \underline{0.55}\ m/s$

Equation of Mechanical Energy: The Energy Equation is a statement of the first law of thermodynamics. The energy equation involves energy, heat transfer and work. With certain limitations the mechanical energy equation can be compared to the Bernoulli Equation and transferred to the Mechanical Energy Equation in Terms of Energy per Unit Mass.

The mechanical energy equation for a **pump or a fan** can be written in terms of **energy per unit mass**:

$p_{in} / \rho + v_{in}^2 / 2 + g\ h_{in} + w_{shaft} = p_{out} / \rho + v_{out}^2 / 2 + g\ h_{out} + w_{loss}$ *(1)*

where

p = static pressure

ρ = density

v = flow velocity

g = acceleration of gravity

h = elevation height

w_{shaft} = net shaft energy inn per unit mass for a pump, fan or similar

w_{loss} = loss due to friction

The energy equation is often used for incompressible flow problems and is called **the Mechanical Energy Equation** or **the Extended Bernoulli Equation**.

The mechanical energy equation for a **turbine** can be written as:

$$p_{in} / \rho + v_{in}^2 / 2 + g\, h_{in} = p_{out} / \rho + v_{out}^2 / 2 + g\, h_{out} + w_{shaft} + w_{loss} \quad (2)$$

where
w_{shaft} = net shaft energy out per unit mass for a turbine or similar

Equation (1) and (2) dimensions are
energy per unit mass (ft^2/s^2 = ft lb/slug or m^2/s^2 = N m/kg)

Efficiency
According to (1) a larger amount of loss - w_{loss} - result in more shaft work required for the same rise of output energy. The efficiency of a **pump or fan process** can be expressed as:

$$\eta = (w_{shaft} - w_{loss}) / w_{shaft} \quad (3)$$

The efficiency of a **turbine process** can be expressed as:

$$\eta = w_{shaft} / (w_{shaft} + w_{loss}) \quad (4)$$

The Mechanical Energy Equation in Terms of Energy per Unit Volume
The mechanical energy equation for a **pump or a fan** (1) can also be written in terms of **energy per unit volume** by multiplying (1) with fluid density - ρ:

$$p_{in} + \rho\, v_{in}^2 / 2 + \gamma\, h_{in} + \rho\, w_{shaft} = p_{out} + \rho\, v_{out}^2 / 2 + \gamma\, h_{out} + w_{loss} \quad (5)$$

where
$\gamma = \rho\, g$ = specific weight

The dimensions of equation (5) are
energy per unit volume (ft.lb/ft^3 = lb/ft^2 or N.m/m^3 = N/m^2)

The Mechanical Energy Equation in Terms of Energy per Unit Weight involves Heads
The mechanical energy equation for a **pump or a fan** (1) can also be written in terms of **energy per unit weight** by dividing with gravity - *g*:

$$p_{in} / \gamma + v_{in}^2 / 2\, g + h_{in} + h_{shaft} = p_{out} / \gamma + v_{out}^2 / 2\, g + h_{out} + h_{loss} \quad (6)$$

where
$\gamma = \rho\, g$ = specific weight
$h_{shaft} = w_{shaft} / g$ = net shaft energy head inn per unit mass for a pump, fan or similar
$h_{loss} = w_{loss} / g$ = loss head due to friction

The dimensions of equation (6) are

energy per unit weight (ft.lb/lb = ft or N.m/N = m)

Head is the energy per unit weight.

h_{shaft} can also be expressed as:
$h_{shaft} = w_{shaft} / g = W_{shaft} / m\, g = W_{shaft} / \gamma\, Q$ *(7)*

where
W_{shaft} *= shaft power*
m = mass flow rate
Q = volume flow rate

Example - Pumping Water
Water is pumped from an open tank at level zero to an open tank at level 10 ft. The pump adds four horsepowers to the water when pumping 2 ft^3/s.
Since $v_{in} = v_{out} = 0$, $p_{in} = p_{out} = 0$ and $h_{in} = 0$ - equation (6) can be modified to:

$h_{shaft} = h_{out} + h_{loss}$
or
$h_{loss} = h_{shaft} - h_{out}$ (8)

Equation (7) gives:

$h_{shaft} = W_{shaft} / \gamma\, Q = (4\ hp)(550\ ft.lb/s/hp) / (62.4\ lb/ft^3)(2\ ft^3/s) = 17.6\ ft$

- specific weight of water 62.4 lb/ft^3
- 1 hp (English horse power) = 550 ft. lb/s

Combined with (8):
$h_{loss} = (17.6\ ft) - (10\ ft) = 7.6\ ft$

The pump efficiency can be calculated from (3) modified for head:
$\eta = ((17.6\ ft) - (7.6\ ft)) / (17.6\ ft) = 0.58$

Equations in Fluid Mechanics: Common fluid mechanics equations - Bernoulli, conservation of energy, conservation of mass, pressure, Navier-Stokes, ideal gas law, Euler equations, Laplace equations, Darcy-Weisbach Equation and the following:

The Bernoulli Equation
- The Bernoulli Equation - A statement of the conservation of energy in a form useful for solving problems involving fluids. For a non-viscous, incompressible fluid in steady flow, the sum of pressure, potential and kinetic energies per unit volume is constant at any point.

Conservation laws
- The conservation laws states that particular measurable properties of an isolated physical system does not change as the system evolves.
- Conservation of energy (including mass)
- Fluid Mechanics and Conservation of Mass - The law of conservation of mass states that mass can neither be created nor destroyed.
- The Continuity Equation - The Continuity Equation is a statement that mass is conserved.

Darcy-Weisbach Equation

- Pressure Loss and Head Loss due to Friction in Ducts and Tubes - Major loss - head loss or pressure loss - due to friction in pipes and ducts.

Euler Equations

- In fluid dynamics, the Euler equations govern the motion of a compressible, inviscid fluid. They correspond to the Navier-Stokes equations with zero viscosity, although they are usually written in the form shown here because this emphasizes the fact that they directly represent conservation of mass, momentum, and energy.

Laplace's Equation

- The Laplace Equation describes the behavior of gravitational, electric, and fluid potentials.

Ideal Gas Law

- The Ideal Gas Law - For a perfect or ideal gas, the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law.
- Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density.
- The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Navier-Stokes Equations

- The motion of a non-turbulent, Newtonian fluid is governed by the Navier-Stokes equations. The equation can be used to model turbulent flow, where the fluid parameters are interpreted as time-averaged values.

Mechanical Energy Equation

- The Mechanical Energy Equation - The mechanical energy equation in Terms of Energy per Unit Mass, in Terms of Energy per Unit Volume and in Terms of Energy per Unit Weight involves Heads.

Pressure

- Static Pressure and Pressure Head in a Fluid - Pressure and pressure head in a static fluid.

Euler Equations: In fluid dynamics, the Euler equations govern the motion of a compressible, inviscid fluid. They correspond to the Navier-Stokes equations with zero viscosity, although they are usually written in the form shown here because this emphasizes the fact that they directly represent conservation of mass, momentum, and energy.

Euler Number: The Euler numbers, also called the secant numbers or zig numbers, are defined for $|x| < \pi/2$ by

$$\operatorname{sech} x - 1 \equiv -\frac{E_1^* x^2}{2!} + \frac{E_2^* x^4}{4!} - \frac{E_3^* x^6}{6!} + \ldots$$

$$\sec x - 1 \equiv \frac{E_1^* x^2}{2!} + \frac{E_2^* x^4}{4!} + \frac{E_3^* x^6}{6!} + \ldots,$$

where $\operatorname{sech}(z)$the hyperbolic secant and sec is the secant. Euler numbers give the number of odd alternating permutations and are related to Genocchi numbers. The base *e* of the natural logarithm is sometimes known as Euler's number. A different sort of Euler number, the Euler number of a finite complex K, is defined by

$$\chi(K) = \sum (-1)^p \operatorname{rank}(C_p(K)).$$

This Euler number is a topological invariant. To confuse matters further, the Euler characteristic is sometimes also called the "Euler number," and numbers produced by the prime-generating polynomial $n^2 - n + 41$ are sometimes called "Euler numbers" (Flannery and Flannery 2000, p. 47).

F

Friction Head: The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type and conditions of conductors and fittings, and the fluid characteristics.

G

Gas: A gas is one of the four major phases of matter (after solid and liquid, and followed by plasma) that subsequently appear as solid material when they are subjected to increasingly higher temperatures. Thus, as energy in the form of heat is added, a solid (e.g., ice) will first melt to become a liquid (e.g., water), which will then boil or evaporate to become a gas (e.g., water vapor). In some circumstances, a solid (e.g., "dry ice") can directly turn into a gas: this is called sublimation. If the gas is further heated, its atoms or molecules can become (wholly or partially) ionized, turning the gas into a plasma. Relater Gas Information: The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Gauge Pressure: Pressure differential above or below ambient atmospheric pressure.

H

Hazen-Williams Factor: Hazen-Williams factor for some common piping materials. Hazen-Williams coefficients are used in the Hazen-Williams equation for friction loss calculation in ducts and pipes.

Hazen-Williams Equation - Calculating Friction Head Loss in Water Pipes
Friction head loss (ft H2O per 100 ft pipe) in water pipes can be obtained by using the empirical Hazen-Williams equation. The Darcy-Weisbach equation with the Moody diagram are considered to be the most accurate model for estimating frictional head loss in steady pipe flow. Since the approach requires a not so efficient trial and error solution, an alternative empirical head loss calculation that does not require the trial and error solutions, as the Hazen-Williams equation, may be preferred:

$$f = 0.2083\ (100/c)^{1.852}\ q^{1.852} / d_h^{4.8655} \quad (1)$$

where
f = friction head loss in feet of water per 100 feet of pipe (ft_{h2o}*/100 ft pipe)*
c = Hazen-Williams roughness constant
q = volume flow (gal/min)

d_h = inside hydraulic diameter (inches)

Note that the Hazen-Williams formula is empirical and lacks physical basis. Be aware that the roughness constants are based on "normal" condition with approximately 1 m/s (3 ft/sec).

The Hazen-Williams formula is not the only empirical formula available. Manning's formula is common for gravity driven flows in open channels.

The flow velocity may be calculated as:

$$v = 0.4087\ q / d_h^2$$

where
v = flow velocity (ft/s)

The Hazen-Williams formula can be assumed to be relatively accurate for piping systems where the Reynolds Number is above 10^5 (turbulent flow).

- 1 ft (foot) = 0.3048 m
- 1 in (inch) = 25.4 mm
- 1 gal (US)/min =6.30888×10^{-5} m^3/s = 0.0227 m^3/h = 0.0631 dm^3(liter)/s = 2.228×10^{-3} ft^3/s = 0.1337 ft^3/min = 0.8327 Imperial gal (UK)/min

Note! The Hazen-Williams formula gives accurate head loss due to friction for fluids with kinematic viscosity of approximately 1.1 cSt. More about fluids and kinematic viscosity.

The results for the formula are acceptable for cold water at 60° F (15.6° C) with kinematic viscosity 1.13 cSt. For hot water with a lower kinematic viscosity (0.55 cSt at 130° F (54.4° C)) the error will be significant. Since the Hazen Williams method is only valid for water flowing at ordinary temperatures between 40 to 75° F, the Darcy Weisbach method should be used for other liquids or gases.

Head: The height of a column or body of fluid above a given point expressed in linear units. Head if often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid. The measure of the pressure of water expressed in feet of height of water. 1 psi = 2.31 feet of water. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

I

Ideal Gas: The Ideal Gas Law - For a perfect or ideal gas the change in density is directly related to the change in temperature and pressure as expressed in the Ideal Gas Law. Properties of Gas Mixtures - Special care must be taken for gas mixtures when using the ideal gas law, calculating the mass, the individual gas constant or the density. The Individual and Universal Gas Constant - The Individual and Universal Gas Constant is common in fluid mechanics and thermodynamics.

Isentropic Compression/Expansion Process: If the compression or expansion takes place under constant volume conditions - the process is called **isentropic.**

The isentropic process on the basis of the Ideal Gas Law can be expressed as:

p / ρ^k = constant (2)

where
$k = c_p / c_v$ - the ratio of specific heats - the ratio of specific heat at constant pressure - c_p - to the specific heat at constant volume - c_v

K

Kinematic Viscosity: The ratio of absolute or dynamic viscosity to density - a quantity in which no force is involved. Kinematic viscosity can be obtained by dividing the absolute viscosity of a fluid with its mass density as

$v = \mu / \rho$ (2)

where
v = kinematic viscosity
μ = absolute or dynamic viscosity
ρ = density

In the SI-system the theoretical unit is m^2/s or commonly used **Stoke (St)** where

- *1 St = 10^{-4} m^2/s*

Since the Stoke is an unpractical large unit, it is usual divided by 100 to give the unit called **Centistokes (cSt)** where
1 St = 100 cSt
1 cSt = 10^{-6} m^2/s

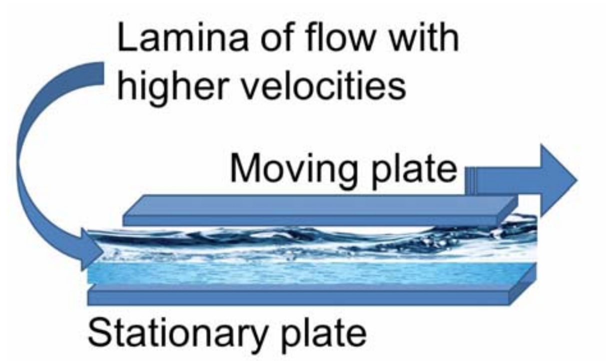
Since the specific gravity of water at 68.4°F (20.2°C) is almost one - 1, the kinematic viscosity of water at 68.4°F is for all practical purposes 1.0 cSt.

Kinetic Energy: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head.

Knudsen Number: Used by modelers who wish to express a non-dimensionless speed.

L

Laminar Flow: The resistance to flow in a liquid can be characterized in terms of the viscosity of the fluid if the flow is smooth. In the case of a moving plate in a liquid, it is found that there is a layer or lamina which moves with the plate, and a layer which is essentially stationary if it is next to a stationary plate. There is a gradient of velocity as you move from the stationary to the moving plate, and the liquid tends to move in layers with successively higher speed. This is called laminar flow, or sometimes "streamlined" flow. Viscous resistance to flow can be modeled for laminar flow, but if the lamina break up into turbulence, it is very difficult to characterize the fluid flow.



The common application of laminar flow would be in the smooth flow of a viscous liquid through a tube or pipe. In that case, the velocity of flow varies from zero at the walls to a maximum along the centerline of the vessel. The flow profile of laminar flow in a tube can be calculated by dividing the flow into thin cylindrical elements and applying the viscous force to them.

Laminar, Transitional or Turbulent Flow? - It is important to know if the fluid flow is laminar, transitional or turbulent when calculating heat transfer or pressure and head loss.

Laplace's Equation: Describes the behavior of gravitational, electric, and fluid potentials.

The scalar form of Laplace's equation is the partial differential equation

$$\nabla^2 \psi = 0, \qquad (1)$$

where ∇^2 is the Laplacian.
Note that the operator ∇^2 is commonly written as $\Delta$by mathematicians (Krantz 1999, p. 16).
Laplace's equation is a special case of the Helmholtz differential equation

$$\nabla^2 \psi + k^2 \psi = 0 \qquad (2)$$

with $k = 0$, or Poisson's equation

$$\nabla^2 \psi = -4\pi\rho \qquad (3)$$

with $\rho = 0$.

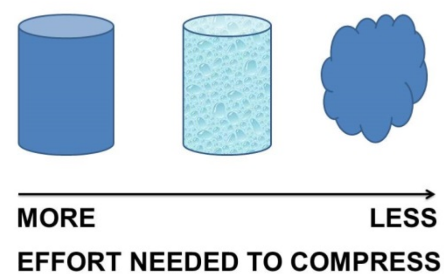
The vector Laplace's equation is given by

$$\nabla^2 \mathbf{F} = \mathbf{0}. \qquad (4)$$

A function ψwhich satisfies Laplace's equation is said to be harmonic. A solution to Laplace's equation has the property that the average value over a spherical surface is equal to the value at the center of the sphere (Gauss's harmonic function theorem). Solutions have no local maxima or minima. Because Laplace's equation is linear, the superposition of any two solutions is also a solution.

Lift (Force): Lift consists of the sum of all the aerodynamic forces normal to the direction of the external airflow.

Liquids: An in-between state of matter. They can be found in between the solid and gas states. They don't have to be made up of the same compounds. If you have a variety of materials in a liquid, it is called a solution. One characteristic of a liquid is that it will fill up the shape of a container. If you pour some water in a cup, it will fill up the bottom of the cup first and then fill the rest. The water will also take the shape of the cup. It fills the bottom first because of **gravity**. The top part of a liquid will usually have a flat surface. That flat surface is because of gravity too. Putting an ice cube (solid) into a cup will leave you with a cube in the middle of the cup; the shape won't change until the ice becomes a liquid.



Another trait of liquids is that they are difficult to compress. When you compress something, you take a certain amount and force it into a smaller space. Solids are very difficult to compress and gases are very easy. Liquids are in the middle but tend to be difficult. When you compress something, you force the atoms closer together. When pressure go up, substances are compressed. Liquids already have their atoms close together, so they are hard to compress. Many shock absorbers in cars compress liquids in tubes.

A special force keeps liquids together. Solids are stuck together and you have to force them apart. Gases bounce everywhere and they try to spread themselves out. Liquids actually want to stick together. There will always be the occasional evaporation where extra energy gets a molecule excited and the molecule leaves the system. Overall, liquids have **cohesive** (sticky) forces at work that hold the molecules together. Related Liquid Information: Equations in Fluid Mechanics - Continuity, Euler, Bernoulli, Dynamic and Total Pressure

M

Mach Number: When an object travels through a medium, then its Mach number is the ratio of the object's speed to the speed of sound in that medium.

Magnetic Flow Meter: Inspection of magnetic flow meter instrumentation should include checking for corrosion or insulation deterioration.

Manning Formula for Gravity Flow: Manning's equation can be used to calculate cross-sectional average velocity flow in open channels

$v = k_n/n\ R^{2/3}\ S^{1/2}$ *(1)*

where
v = cross-sectional average velocity (ft/s, m/s)
k_n *= 1.486 for English units and* k_n *= 1.0 for SI units*
A = cross sectional area of flow (ft^2, m^2)
n = Manning coefficient of roughness
R = hydraulic radius (ft, m)
S = slope of pipe (ft/ft, m/m)

The volume flow in the channel can be calculated as
$q = A\ v = A\ k_n/n\ R^{2/3}\ S^{1/2}$ *(2)*

where
q = volume flow (ft³/s, m³/s)
A = cross-sectional area of flow (ft², m²)

Maximum Contamination Levels or (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL. Or provide adequate backflow protection.

Mechanical Seal: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them.

Mg/L: milligrams per liter

Microbe, Microbial: Any minute, simple, single-celled form of life, especially one that causes disease.

Microbial Contaminants: Microscopic organisms present in untreated water that can cause waterborne diseases.

ML: milliliter

N

Navier-Stokes Equations: The motion of a non-turbulent, Newtonian fluid is governed by the Navier-Stokes equation. The equation can be used to model turbulent flow, where the fluid parameters are interpreted as time-averaged values.

Newtonian Fluid: Newtonian fluid (named for Isaac Newton) is a fluid that flows like water—its shear stress is linearly proportional to the velocity gradient in the direction perpendicular to the plane of shear. The constant of proportionality is known as the viscosity. Water is Newtonian, because it continues to exemplify fluid properties no matter how fast it is stirred or mixed.

Contrast this with a non-Newtonian fluid, in which stirring can leave a "hole" behind (that gradually fills up over time - this behavior is seen in materials such as pudding, or to a less rigorous extent, sand), or cause the fluid to become thinner, the drop in viscosity causing it to flow more (this is seen in non-drip paints). For a Newtonian fluid, the viscosity, by definition, depends only on temperature and pressure (and also the chemical composition of the fluid if the fluid is not a pure substance), not on the forces acting upon it. If the fluid is incompressible and viscosity is constant across the fluid, the equation governing the shear stress. Related Newtonian Information: A Fluid is Newtonian if viscosity is constant applied to shear force. Dynamic, Absolute and Kinematic Viscosity - An introduction to dynamic, absolute and kinematic viscosity and how to convert between CentiStokes (cSt), CentiPoises (cP), Saybolt Universal Seconds (SSU) and degree Engler.

Newton's Third Law: Newton's third law describes the forces acting on objects interacting with each other. Newton's third law can be expressed as

- *"If one object exerts a force **F** on another object, then the second object exerts an equal but opposite force **F** on the first object"*

Force is a convenient abstraction to represent mentally the pushing and pulling interaction between objects.

It is common to express forces as vectors with magnitude, direction and point of application. The net effect of two or more forces acting on the same point is the vector sum of the forces.

Non-Newtonian Fluid: Non-Newtonian fluid viscosity changes with the applied shear force.

P

Pascal's Law: A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

pCi/L- ***picocuries per liter:*** A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.
pH: A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. pH (Power of Hydroxyl Ion Activity).

Peak Demand: The maximum momentary load placed on a water treatment plant, pumping station or distribution system is the Peak Demand.

Pipe Velocities: For calculating fluid pipe velocity.

Imperial units
A fluids flow velocity in pipes can be calculated with Imperial or American units as

$v = 0.4085\ q / d^2$ (1)

where
v = velocity (ft/s)
q = volume flow (US gal. /min)
d = pipe inside diameter (inches)

SI units
A fluids flow velocity in pipes can be calculated with SI units as

$v = 1.274\ q / d^2$ (2)

where
v = velocity (m/s)
q = volume flow (m^3/s)
d = pipe inside diameter (m)

Potential Energy: The energy that a body has by virtue of its position or state enabling it to do work.

PPM: Abbreviation for parts per million.

Prandtl Number: The Prandtl Number is a dimensionless number approximating the ratio of momentum diffusivity and thermal diffusivity and can be expressed as

$Pr = v / \alpha$ (1)
where
Pr = Prandtl's number
v = kinematic viscosity (Pa s)
α = thermal diffusivity (W/m K)

The Prandtl number can alternatively be expressed as

$Pr = \mu c_p / k$ (2)

where
μ = absolute or dynamic viscosity (kg/m s, cP)
c_p = specific heat capacity (J/kg K, Btu/(lb ^oF))
k = thermal conductivity (W/m K, Btu/(h ft^2 ^oF/ft))
The Prandtl Number is often used in heat transfer and free and forced convection calculations.

Pressure: An introduction to pressure - the definition and presentation of common units as psi and Pa and the relationship between them.

The pressure in a fluid is defined as
"the normal force per unit area exerted on an imaginary or real plane surface in a fluid or a gas"

The equation for pressure can expressed as:
$p = F / A$ (1)

where
p = pressure [lb/in^2 (psi) or lb/ft^2 (psf), N/m^2 or kg/ms^2 (Pa)]
F = force [1), N]
A = area [in^2 or ft^2, m^2]
1) In the English Engineering System special care must be taken for the force unit. The basic unit for mass is the pound mass (lb_m) and the unit for the force is the pound (lb) or pound force (lb_f).

Absolute Pressure
The **absolute pressure** - p_a - is measured relative to the *absolute zero pressure* - the pressure that would occur at absolute vacuum.

Gauge Pressure
A **gauge** is often used to measure the pressure difference between a system and the surrounding atmosphere. This pressure is often called the **gauge pressure** and can be expressed as
$p_g = p_a - p_o$ (2)

where
p_g = gauge pressure

p_o = atmospheric pressure

Atmospheric Pressure
The atmospheric pressure is the pressure in the surrounding air. It varies with temperature and altitude above sea level.

Standard Atmospheric Pressure
The **Standard Atmospheric Pressure** (atm) is used as a reference for gas densities and volumes. The Standard Atmospheric Pressure is defined at sea-level at 273°K (0°C) and is **1.01325 bar** or 101325 Pa (absolute). The temperature of 293°K (20°C) is also used.

In imperial units the Standard Atmospheric Pressure is 14.696 psi.
- *1 atm = 1.01325 bar = 101.3 kPa = 14.696 psi (lb_f/in^2)= 760 mmHg =10.33 mH_2O = 760 torr = 29.92 in Hg = 1013 mbar = 1.0332 kg_f/cm^2 = 33.90 ftH_2O*

Pressure Head: The height to which liquid can be raised by a given pressure.

Pressure Units: Since 1 Pa is a small pressure unit, the unit hectopascal (hPa) is widely used, especially in meteorology. The unit kilopascal (kPa) is commonly used designing technical applications like HVAC systems, piping systems and similar.
- *1 hectopascal = 100 pascal = 1 millibar*
- *1 kilopascal = 1000 pascal*

Some Pressure Levels
- 10 Pa - The pressure at a depth of 1 mm of water
- 1 kPa - Approximately the pressure exerted by a 10 g mass on a 1 cm^2 area
- 10 kPa - The pressure at a depth of 1 m of water, or
  the drop in air pressure when going from sea level to 1000 m elevation
- 10 MPa - A "high pressure" washer forces the water out of the nozzles at this pressure
- 10 GPa - This pressure forms diamonds

Some Alternative Units of Pressure
- *1 bar - 100,000 Pa*
- *1 millibar - 100 Pa*
- *1 atmosphere - 101,325 Pa*
- *1 mm Hg - 133 Pa*
- *1 inch Hg - 3,386 Pa*

A **torr** (torr) is named after Torricelli and is the pressure produced by a column of mercury 1 mm high equals to 1/760th of an atmosphere. 1 atm = 760 torr = 14.696 psi

Pounds per square inch (psi) was common in U.K. but has now been replaced in almost every country except in the U.S. by the SI units. The Normal atmospheric pressure is 14.696 psi, meaning that a column of air on one square inch in area rising from the Earth's atmosphere to space weighs 14.696 pounds.

The **bar** (bar) is common in the industry. One bar is 100,000 Pa, and for most practical purposes can be approximated to one atmosphere even if

1 Bar = 0.9869 atm

There are 1,000 **millibar** (mbar) in one bar, a unit common in meteorology.

1 millibar = 0.001 bar = 0.750 torr = 100 Pa

Q

R

Residual Disinfection/Protection: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).

Reynolds Number: The Reynolds number is used to determine whether a flow is laminar or turbulent. The Reynolds Number is a non-dimensional parameter defined by the ratio of dynamic pressure (ρu^2) and shearing stress ($\mu u / L$) - and can be expressed as

$$Re = (\rho u^2) / (\mu u / L)$$
$$= \rho u L / \mu$$
$$= u L / v \quad (1)$$

where

Re = Reynolds Number (non-dimensional)

ρ = *density* (kg/m^3, lb_m/ft^3)

u = velocity (m/s, ft/s)

μ = *dynamic viscosity* (Ns/m^2, $lb_m/s\ ft$)

L = characteristic length (m, ft)

v = kinematic viscosity (m^2/s, ft^2/s)

Richardson Number: A dimensionless number that expresses the ratio of potential to kinetic energy.

S

Saybolt Universal Seconds (or SUS, SSU): Saybolt Universal Seconds (or SUS) is used to measure viscosity. The efflux time is Saybolt Universal Seconds (SUS) required for 60 milliliters of a petroleum product to flow through the calibrated orifice of a Saybolt Universal viscometer, under carefully controlled temperature and as prescribed by test method ASTM D 88. This method has largely been replaced by the kinematic viscosity method. Saybolt Universal Seconds is also called the SSU number (Seconds Saybolt Universal) or SSF number (Saybolt Seconds Furol).

Kinematic viscosity versus dynamic or absolute viscosity can be expressed as

$$v = 4.63\ \mu / SG \quad (3)$$

where

v = kinematic viscosity (SSU)

μ = *dynamic or absolute viscosity (cP)*

Specific Gravity: The Specific Gravity - *SG* - is a dimensionless unit defined as the ratio of density of the material to the density of water at a specified temperature. Specific Gravity can be expressed as

$SG = = \rho / \rho_{H2O}$ (3)

where
SG = specific gravity
ρ = density of fluid or substance (kg/m^3)
ρ_{H2O} = density of water (kg/m^3)

It is common to use the density of water at 4° C (39°F) as a reference - at this point the density of water is at the highest. Since Specific Weight is dimensionless it has the same value in the metric SI system as in the imperial English system (BG). At the reference point the Specific Gravity has same numerically value as density.

Example - Specific Gravity
If the density of iron is 7850 kg/m^3, 7.85 grams per cubic millimeter, 7.85 kilograms per liter, or 7.85 metric tons per cubic meter - the specific gravity of iron is:

$SG = 7850\ kg/m^3 / 1000\ kg/m^3$
= <u>*7.85*</u>
(the density of water is 1000 kg/m^3)

Specific Weight: Specific Weight is defined as weight per unit volume. Weight is a **force**.

- Mass and Weight - the difference! - What is weight and what is mass? An explanation of the difference between weight and mass.

Specific Weight can be expressed as

$\gamma = \rho\ g$ (2)

where
γ = specific weight (kN/m^3)
g = acceleration of gravity (m/s^2)

The SI-units of specific weight are kN/m^3. The imperial units are lb/ft^3. The local acceleration *g* is under normal conditions 9.807 m/s^2 in SI-units and 32.174 ft/s^2 in imperial units.

Example - Specific Weight Water
Specific weight for water at 60 °F is 62.4 lb/ft^3 in imperial units and 9.80 kN/m^3 in SI-units.

Example - Specific Weight Some other Materials

Product	Specific Weight - γ	
	Imperial Units (lb/ft^3)	SI Units (kN/m^3)
Ethyl Alcohol	49.3	7.74
Gasoline	42.5	6.67
Glycerin	78.6	12.4
Mercury	847	133
SAE 20 Oil	57	8.95
Seawater	64	10.1
Water	62.4	9.80

Static Head: The height of a column or body of fluid above a given point

Static Pressure: The pressure in a fluid at rest.

Static Pressure and Pressure Head in Fluids: The pressure indicates the normal force per unit area at a given point acting on a given plane. Since there is no shearing stresses present in a fluid at rest - the pressure in a fluid is independent of direction.

For fluids - liquids or gases - at rest the pressure gradient in the vertical direction depends only on the specific weight of the fluid.

How pressure changes with elevation can be expressed as

$dp = - \gamma\, dz$ *(1)*

where
dp = change in pressure
dz = change in height
γ = specific weight

The pressure gradient in vertical direction is negative - the pressure decrease upwards.

Specific Weight: Specific Weight can be expressed as:

$\gamma = \rho\, g$ *(2)*

where
γ = specific weight
g = acceleration of gravity

In general the specific weight - *γ* - is constant for fluids. For gases the specific weight - *γ* - varies with the elevation.

Static Pressure and Pressure Head in Fluids:
Static Pressure in a Fluid: For an incompressible fluid - as a liquid - the pressure difference between two elevations can be expressed as:

$p_2 - p_1 = - \gamma (z_2 - z_1)$ *(3)*

where
p_2 = *pressure at level 2*
p_1 = *pressure at level 1*
z_2 = *level 2*
z_1 = *level 1*

(3) can be transformed to:

$p_1 - p_2 = \gamma (z_2 - z_1)$ *(4)*
or
$p_1 - p_2 = \gamma\, h$ *(5)*

where
$h = z_2 - z_1$ *difference in elevation - the depth down from location* z_2.
or
$p_1 = \gamma\, h + p_2$ *(6)*

Static Pressure and Pressure Head in Fluids Continued:

The Pressure Head

(6) can be transformed to:

$$h = (p_2 - p_1) / \gamma \ (6)$$

h express **the pressure head** - the height of a column of fluid of specific weight - *γ* - required to give a pressure difference of ($p_2 - p_1$).

Example - Pressure Head

A pressure difference of 5 psi (lbf/in^2) is equivalent to

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 62.4 (lb/ft^3) = <u>11.6</u> ft of water

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 847 (lb/ft^3) = <u>0.85</u> ft of mercury

when specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).

Streamline - Stream Function: A streamline is the path that an imaginary particle would follow if it was embedded in the flow.

Strouhal Number: A quantity describing oscillating flow mechanisms. **The Strouhal Number** is a dimensionless value useful for analyzing oscillating, unsteady fluid flow dynamics problems.

The Strouhal Number can be expressed as

$$St = \omega l / v \ (1)$$

where
St = Strouhal Number
ω = oscillation frequency
l = characteristic length
v = flow velocity

The Strouhal Number represents a measure of the ratio of inertial forces due to the unsteadiness of the flow or local acceleration to the inertial forces due to changes in velocity from one point to another in the flow field.

The vortices observed behind a stone in a river, or measured behind the obstruction in a vortex flow meter, illustrate these principles.

Surface Tension: Surface tension is a force within the surface layer of a liquid that causes the layer to behave as an elastic sheet. The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules at the surface do not have other like molecules on all sides of them and consequently they cohere more strongly to those directly associated with them on the surface. This forms a surface "film" which makes it more difficult to move an object through the surface than to move it when it is completely submersed. Surface tension is typically measured in dynes/cm, the force in dynes required to break a film of length 1 cm. Equivalently, it can be stated as surface energy in ergs per square centimeter. Water at 20°C has a surface tension of 72.8 dynes/cm compared to 22.3 for ethyl alcohol and 465 for mercury.

Surface tension is typically measured in *dynes/cm* or *N/m*.

Liquid	Surface Tension	
	N/m	dynes/cm
Ethyl Alcohol	0.0223	22.3
Mercury	0.465	465
Water 20^{o}C	0.0728	72.75
Water 100^{o}C	0.0599	58.9

Surface tension is the energy required to stretch a unit change of a surface area. Surface tension will form a drop of liquid to a sphere since the sphere offers the smallest area for a definite volume.

Surface tension can be defined as

$\sigma = F_s / l$ *(1)*

where
σ = surface tension (N/m)
F_s = stretching force (N)
l = unit length (m)

Alternative Units
Alternatively, surface tension is typically measured in dynes/cm, which is

- the force in dynes required to break a film of length 1 cm

or as surface energy J/m^2 or alternatively ergs per square centimeter.

- 1 dynes/cm = 0.001 N/m = 0.0000685 lb_f/ft = 0.571 10^{-5} lb_f/in = 0.0022 poundal/ft = 0.00018 poundal/in = 1.0 mN/m = 0.001 J/m^2 = 1.0 erg/cm^2 = 0.00010197 kg_f/m

Common Imperial units used are lb/ft and lb/in.

Water surface tension at different temperatures can be taken from the table below:

Temperature (^{o}C)	Surface Tension - σ - (N/m)
0	0.0757
10	0.0742
20	0.0728
30	0.0712
40	0.0696
50	0.0679
60	0.0662
70	0.0644
80	0.0626
90	0.0608
100	0.0588

Surface Tension of some common Fluids

- benzene : 0.0289 (N/m)
- diethyl ether : 0.0728 (N/m)
- carbon tetrachloride : 0.027 (N/m)
- chloroform : 0.0271 (N/m)
- ethanol : 0.0221 (N/m)
- ethylene glycol : 0.0477 (N/m)
- glycerol : 0.064 (N/m)
- mercury : 0.425 (N/m)
- methanol : 0.0227 (N/m)
- propanol : 0.0237 (N/m)
- toluene : 0.0284 (N/m)
- water at 20^oC : 0.0729 (N/m)

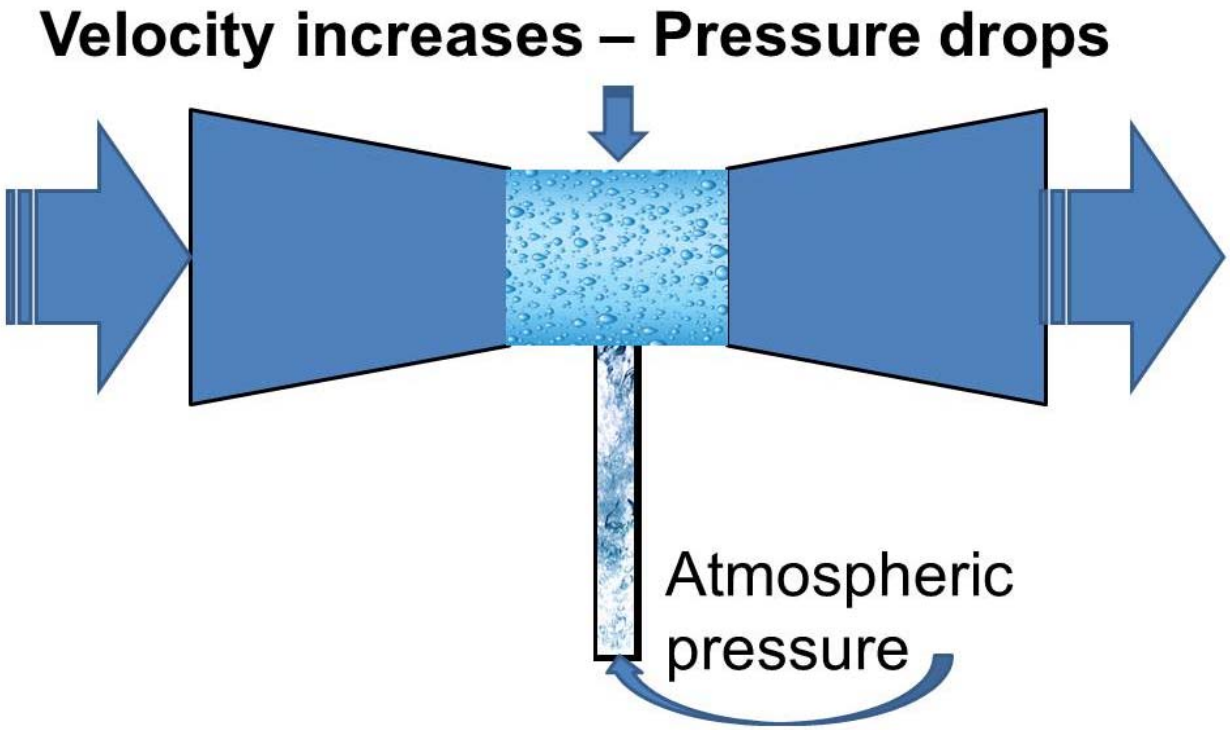
T

U

V

Venturi: A system for speeding the flow of the fluid, by constricting it in a cone-shaped tube. Venturi are used to measure the speed of a fluid, by measuring the pressure changes from one point to another along the venture. A venturi can also be used to inject a liquid or a gas into another liquid. A pump forces the liquid flow through a tube connected to:

- A venturi to increase the speed of the fluid (restriction of the pipe diameter)
- A short piece of tube connected to the gas source
- A second venturi that decrease the speed of the fluid (the pipe diameter increase again)
- After the first venturi the pressure in the pipe is lower, so the gas is sucked in the pipe. Then the mixture enters the second venturi and slow down. At the end of the system a mixture of gas and liquid appears and the pressure rise again to its normal level in the pipe.
- This technique is used for ozone injection in water.



The newest injector design causes complete mixing of injected materials (air, ozone or chemicals), eliminating the need for other in-line mixers. Venturi injectors have no moving parts and are maintenance free. They operate effectively over a wide range of pressures (from 1 to 250 psi) and require only a minimum pressure difference to initiate the vacuum at the suction part. Venturis are often built in thermoplastics (PVC, PE, PVDF), stainless steel or other metals.

The cavitation effect at the injection chamber provides an instantaneous mixing, creating thousands of very tiny bubbles of gas in the liquid. The small bubbles provide and increased gas exposure to the liquid surface area, increasing the effectiveness of the process (i.e. ozonation).

Viscosity: Informally, viscosity is the quantity that describes a fluid's resistance to flow. Fluids resist the relative motion of immersed objects through them as well as to the motion of layers with differing velocities within them. Formally, viscosity (represented by the symbol η "eta") is the ratio of the shearing stress (F/A) to the velocity gradient ($\Delta v_x/\Delta z$ or dv_x/dz) in a fluid.

$$\eta = \left(\frac{F}{A}\right) \div \left(\frac{\Delta v_x}{\Delta z}\right) \quad \text{or} \quad \eta = \left(\frac{F}{A}\right) \div \left(\frac{dv_x}{dz}\right)$$

The more usual form of this relationship, called Newton's equation, states that the resulting shear of a fluid is directly proportional to the force applied and inversely proportional to its viscosity. The similarity to Newton's second law of motion ($F = ma$) should be apparent.

$$\frac{F}{A} = \eta \frac{\Delta v_x}{\Delta z} \quad \text{or} \quad \frac{F}{A} = \eta \frac{dv_x}{dz}$$

$$\Updownarrow \qquad\qquad \Updownarrow$$

$$F = m\frac{\Delta v}{\Delta t} \quad \text{or} \quad F = m\frac{dv}{dt}$$

The SI unit of viscosity is the pascal second [Pa·s], which has no special name. Despite its self-proclaimed title as an international system, the International System of Units has had very little international impact on viscosity. The pascal second is rarely used in scientific and technical publications today. The most common unit of viscosity is the dyne second per square centimeter [dyne·s/cm^2], which is given the name poise [P] after the French physiologist Jean Louis Poiseuille (1799-1869). Ten poise equal one pascal second [Pa·s] making the centipoise [cP] and millipascal second [mPa·s] identical.

1 pascal second = 10 poise = 1,000 millipascal second
1 centipoise = 1 millipascal second

There are actually two quantities that are called viscosity. The quantity defined above is sometimes called dynamic viscosity, absolute viscosity, or simple viscosity to distinguish it from the other quantity, but is usually just called viscosity. The other quantity called kinematic viscosity (represented by the symbol v "nu") is the ratio of the viscosity of a fluid to its density.

$$v = \frac{\eta}{\rho}$$

Kinematic viscosity is a measure of the resistive flow of a fluid under the influence of gravity. It is frequently measured using a device called a capillary viscometer -- basically a graduated can with a narrow tube at the bottom. When two fluids of equal volume are placed in identical capillary viscometers and allowed to flow under the influence of gravity, a viscous fluid takes longer than a less viscous fluid to flow through the tube. Capillary viscometers are discussed in more detail later in this section. The SI unit of kinematic viscosity is the square meter per second [m^2/s], which has no special name. This unit is so large that it is rarely used. A more common unit of kinematic viscosity is the square centimeter per second [cm^2/s], which is given the name stoke [St] after the English scientist George Stoke. This unit is also a bit too large and so the most common unit is probably the square millimeter per second [mm^2/s] or centistoke [cSt].

Viscosity and Reference Temperatures: The viscosity of a fluid is highly temperature dependent and for either dynamic or kinematic viscosity to be meaningful, the **reference temperature** must be quoted. In ISO 8217 the reference temperature for a residual fluid is 100^{o}C. For a distillate fluid the reference temperature is 40^{o}C.

- For a liquid - the kinematic viscosity will **decrease** with higher temperature.
- For a gas - the kinematic viscosity will **increase** with higher temperature.

Vorticity: Vorticity is defined as the circulation per unit area at a point in the flow field.

Appendixes and Charts
Density of Common Liquids
The density of some common liquids can be found in the table below:

Liquid	Temperature - *t* - (^oC)	Density - *ρ* - (kg/m^3)
Acetic Acid	25	1049
Acetone	25	785
Acetonitrile	20	782
Alcohol, ethyl	25	785
Alcohol, methyl	25	787
Alcohol, propyl	25	780
Ammonia (aqua)	25	823
Aniline	25	1019
Automobile oils	15	880 - 940
Beer (varies)	10	1010
Benzene	25	874
Benzyl	15	1230
Brine	15	1230
Bromine	25	3120
Butyric Acid	20	959
Butane	25	599
n-Butyl Acetate	20	880
n-Butyl Alcohol	20	810
n-Butylhloride	20	886
Caproic acid	25	921
Carbolic acid	15	956
Carbon disulfide	25	1261
Carbon tetrachloride	25	1584
Carene	25	857
Castor oil	25	956
Chloride	25	1560
Chlorobenzene	20	1106
Chloroform	20	1489
Chloroform	25	1465
Citric acid	25	1660
Coconut oil	15	924
Cotton seed oil	15	926
Cresol	25	1024

Creosote	15	1067
Crude oil, 48º API	60ºF	790
Crude oil, 40º API	60ºF	825
Crude oil, 35.6º API	60ºF	847
Crude oil, 32.6º API	60ºF	862
Crude oil, California	60ºF	915
Crude oil, Mexican	60ºF	973
Crude oil, Texas	60ºF	873
Cumene	25	860
Cyclohexane	20	779
Cyclopentane	20	745
Decane	25	726
Diesel fuel oil 20 to 60	15	820 - 950
Diethyl ether	20	714
o-Dichlorobenzene	20	1306
Dichloromethane	20	1326
Diethylene glycol	15	1120
Dichloromethane	20	1326
Dimethyl Acetamide	20	942
N,N-Dimethylformamide	20	949
Dimethyl Sulfoxide	20	1100
Dodecane	25	755
Ethane	-89	570
Ether	25	73
Ethylamine	16	681
Ethyl Acetate	20	901
Ethyl Alcohol	20	789
Ethyl Ether	20	713
Ethylene Dichloride	20	1253
Ethylene glycol	25	1097
Fluorine refrigerant R-12	25	1311
Formaldehyde	45	812
Formic acid 10%oncentration	20	1025
Formic acid 80%oncentration	20	1221
Freon - 11	21	1490
Freon - 21	21	1370
Fuel oil	60ºF	890

Furan	25	1416
Furforol	25	1155
Gasoline, natural	60ºF	711
Gasoline, Vehicle	60ºF	737
Gas oils	60ºF	890
Glucose	60ºF	1350 - 1440
Glycerin	25	1259
Glycerol	25	1126
Heptane	25	676
Hexane	25	655
Hexanol	25	811
Hexene	25	671
Hydrazine	25	795
Iodine	25	4927
Ionene	25	932
Isobutyl Alcohol	20	802
Iso-Octane	20	692
Isopropyl Alcohol	20	785
Isopropyl Myristate	20	853
Kerosene	60ºF	817
Linolenic Acid	25	897
Linseed oil	25	929
Methane	-164	465
Methanol	20	791
Methyl Isoamyl Ketone	20	888
Methyl Isobutyl Ketone	20	801
Methyl n-Propyl Ketone	20	808
Methyl t-Butyl Ether	20	741
N-Methylpyrrolidone	20	1030
Methyl Ethyl Ketone	20	805
Milk	15	1020 - 1050
Naphtha	15	665
Naphtha, wood	25	960
Napthalene	25	820
Ocimene	25	798
Octane	15	918
Olive oil	20	800 - 920
Oxygen (liquid)	-183	1140
Palmitic Acid	25	851

Pentane	20	626
Pentane	25	625
Petroleum Ether	20	640
Petrol, natural	60°F	711
Petrol, Vehicle	60°F	737
Phenol	25	1072
Phosgene	0	1378
Phytadiene	25	823
Pinene	25	857
Propane	-40	583
Propane, R-290	25	494
Propanol	25	804
Propylenearbonate	20	1201
Propylene	25	514
Propylene glycol	25	965
Pyridine	25	979
Pyrrole	25	966
Rape seed oil	20	920
Resorcinol	25	1269
Rosin oil	15	980
Sea water	25	1025
Silane	25	718
Silicone oil		760
Sodium Hydroxide (caustic soda)	15	1250
Sorbaldehyde	25	895
Soya bean oil	15	924 - 928
Stearic Acid	25	891
Sulfuric Acid 95%onc.	20	1839
Sugar solution 68 brix	15	1338
Sunflower oil	20	920
Styrene	25	903
Terpinene	25	847
Tetrahydrofuran	20	888
Toluene	20	867
Toluene	25	862
Triethylamine	20	728
Trifluoroacetic Acid	20	1489
Turpentine	25	868

Water - pure	4	1000
Water - sea	77°F	1022
Whale oil	15	925
o-Xylene	20	880

1 kg/m^3 = 0.001 g/cm^3 = 0.0005780 oz/in^3 = 0.16036 oz/gal (Imperial) = 0.1335 oz/gal (U.S.) = 0.0624 lb/ft^3 = 0.000036127 lb/in^3 = 1.6856 lb/yd^3 = 0.010022 lb/gal (Imperial) = 0.008345 lb/gal (U.S) = 0.0007525 ton/yd^3

Dynamic or Absolute Viscosity Units Converting Table

The table below can be used to convert between common dynamic or absolute viscosity units.

Multiply by	Convert to				
Convert from	Poiseuille (Pa s)	Poise (dyne s/ cm^2 = g / cm s)	centiPoise	kg / m h	kg_f s / m^2
Poiseuille (Pa s)	1	10	10^3	3.63 10^3	0.102
Poise (dyne s / cm^2 = g / cm s)	0.1	1	100	360	0.0102
centiPoise	0.001	0.01	1	3.6	0.00012
kg / m h	2.78 10^{-4}	0.00278	0.0278	1	2.83 10^{-5}
kg_f s / m^2	9.81	98.1	9.81 10^3	3.53 10^4	1
lb_f s / $inch^2$	6.89 10^3	6.89 10^4	6.89 10^6	2.48 10^7	703
lb_f s / ft^2	47.9	479	4.79 10^4	1.72 10^5	0.0488
lb_f h / ft^2	1.72 10^5	1.72 10^6	1.72 10^8	6.21 10^8	1.76 10^4
lb / ft s	1.49	14.9	1.49 10^3	5.36 10^3	0.152
lb / ft h	4.13 10^{-4}	0.00413	0.413	1.49	4.22 10^{-5}

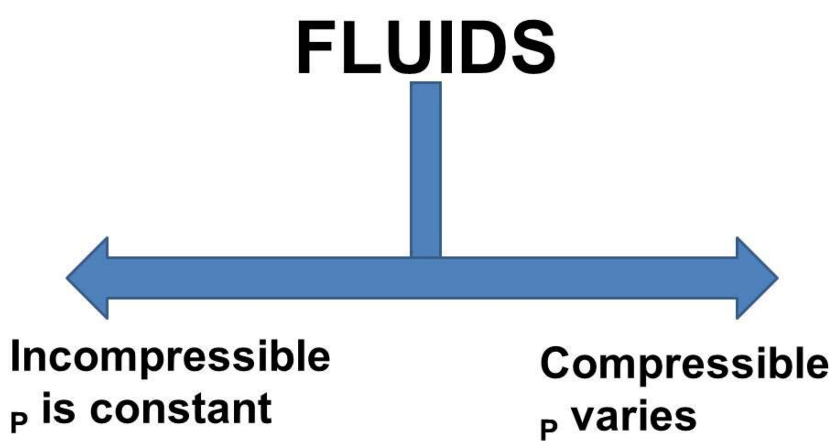
Multiply by	Convert to				
Convert from	lb_f s / $inch^2$	lb_f s / ft^2	lb_f h / ft^2	lb / ft s	lb / ft h
Poiseuille (Pa s)	1.45 10^{-4}	0.0209	5.8 10^{-6}	0.672	2.42 10^3
Poise (dyne s / cm^2 = g / cm s)	1.45 10^{-5}	0.00209	5.8 10^{-7}	0.0672	242
centiPoise	1.45 10^{-7}	2.9 10^{-5}	5.8 10^{-9}	0.000672	2.42
kg / m h	4.03 10^{-8}	5.8 10^{-6}	1.61 10^{-9}	0.000187	0.672
kg_f s / m^2	0.00142	20.5	5.69 10^{-5}	6.59	2.37 10^4
lb_f s / $inch^2$	1	144	0.04	4.63 10^3	1.67 10^7
lb_f s / ft^2	0.00694	1	0.000278	32.2	1.16 10^5
lb_f h / ft^2	25	3.6 10^3	1	1.16 10^5	4.17 10^8
lb / ft s	0.000216	0.0311	8.63 10^{-6}	1	3.6 10^3
lb / ft h	6 10^{-8}	1.16 10^5	2.4 10^{-9}	0.000278	1

Friction Loss Chart

The table below can be used to indicate the friction loss - feet of liquid per 100 feet of pipe - in standard schedule 40 steel pipes.

Pipe Size (inches)	Flow Rate		Kinematic Viscosity - SSU					
	(gpm)	(l/s)	31 (Water)	100 (~Cream)	200 (~Vegetable oil)	400 (~SAE 10 oil)	800 (~Tomato juice)	1500 (~SAE 30 oil)
1/2	3	0.19	10.0	25.7	54.4	108.0	218.0	411.0
3/4	3	0.19	2.5	8.5	17.5	35.5	71.0	131.0
	5	0.32	6.3	14.1	29.3	59.0	117.0	219.0
1	3	0.19	0.8	3.2	6.6	13.4	26.6	50.0
	5	0.32	1.9	5.3	11.0	22.4	44.0	83.0
	10	0.63	6.9	11.2	22.4	45.0	89.0	165.0
	15	0.95	14.6	26.0	34.0	67.0	137.0	
	20	1.26	25.1	46	46.0	90.0	180.0	
1 1/4	5	0.32	0.5	1.8	3.7	7.6	14.8	26.0
	10	0.63	1.8	3.6	7.5	14.9	30.0	55.0
	15	0.95	3.7	6.4	11.3	22.4	45.0	84.0
1 1/2	10	0.63	0.8	1.9	4.2	8.1	16.5	31.0
	15	0.95	1.7	2.8	6.2	12.4	25.0	46.0
	20	1.26	2.9	5.3	8.1	16.2	33.0	61.0
	30	1.9	6.3	11.6	12.2	24.3	50.0	91.0
	40	2.5	10.8	19.6	20.8	32.0	65.0	121.0
2	20	1.26	0.9	1.5	3.0	6.0	11.9	22.4
	30	1.9	1.8	3.2	4.4	9.0	17.8	33.0
	40	2.5	3.1	5.8	5.8	11.8	24.0	44.0
	60	3.8	6.6	11.6	13.4	17.8	36.0	67.0
	80	5.0	1.6	3.0	3.2	4.8	9.7	18.3
2 1/2	30	1.9	0.8	1.4	2.2	4.4	8.8	16.6
	40	2.5	1.3	2.5	3.0	5.8	11.8	22.2
	60	3.8	2.7	5.1	5.5	8.8	17.8	34.0
	80	5.0	4.7	8.3	9.7	11.8	24.0	44.0
	100	6.3	7.1	12.2	14.1	14.8	29.0	55.0
3	60	3.8	0.9	1.8	1.8	3.7	7.3	13.8
	100	6.3	2.4	4.4	5.1	6.2	12.1	23.0
	125	7.9	3.6	6.5	7.8	8.1	15.3	29.0
	150	9.5	5.1	9.2	10.4	11.5	18.4	35.0
	175	11.0	6.9	11.7	13.8	15.8	21.4	40.0
	200	12.6	8.9	15.0	17.8	20.3	25.0	46.0

4	80	5.0	0.4	0.8	0.8	1.7	3.3	6.2
	100	6.3	0.6	1.2	1.3	2.1	4.1	7.8
	125	7.9	0.9	1.8	2.1	2.6	5.2	9.8
	150	9.5	1.3	2.4	2.9	3.1	6.2	11.5
	175	11.0	1.8	3.2	4.0	4.0	7.4	13.7
	200	12.6	2.3	4.2	5.1	5.1	8.3	15.5
	250	15.8	3.5	6.0	7.4	8.0	10.2	19.4
6	125	7.9	0.1	0.3	0.3	0.52	1.0	1.9
	150	9.5	0.2	0.3	0.4	0.6	1.2	2.3
	175	11.0	0.2	0.4	0.5	0.7	1.4	2.6
	200	12.6	0.3	0.6	0.7	0.8	1.6	3.0
	250	15.8	0.5	0.8	1.0	1.0	2.1	3.7
	300	18.9	1.1	8.5	10.0	11.6	12.4	23.0
	400	25.2	1.1	1.9	2.3	2.8	3.2	6.0
8	250	15.8	0.1	0.2	0.3	0.4	0.7	1.2
	300	18.9	0.3	1.2	1.4	1.5	2.5	4.6
	400	25.2	0.3	0.5	0.6	0.7	1.1	2.0
10	300	18.9	0.1	0.3	0.4	0.4	0.8	1.5
	400	25.2	0.1	0.2	0.2	0.2	0.4	0.8



Hazen-Williams Coefficients

Hazen-Williams factor for some common piping materials. Hazen-Williams coefficients are used in the Hazen-Williams equation for friction loss calculation in ducts and pipes. Coefficients for some common materials used in ducts and pipes can be found in the table below:

Material	Hazen-Williams Coefficient - *C* -
Asbestos Cement	140
Brass	130 - 140
Brick sewer	100
Cast-Iron - new unlined (CIP)	130
Cast-Iron 10 years old	107 - 113
Cast-Iron 20 years old	89 - 100
Cast-Iron 30 years old	75 - 90
Cast-Iron 40 years old	64-83
Cast-Iron, asphalt coated	100
Cast-Iron, cement lined	140
Cast-Iron, bituminous lined	140
Cast-Iron, wrought plain	100
Concrete	100 - 140
Copper or Brass	130 - 140
Ductile Iron Pipe (DIP)	140
Fiber	140
Galvanized iron	120
Glass	130
Lead	130 - 140
Plastic	130 - 150
Polyethylene, PE, PEH	150
PVC, CPVC	150
Smooth Pipes	140
Steel new unlined	140 - 150
Steel	
Steel, welded and seamless	100
Steel, interior riveted, no projecting rivets	100
Steel, projecting girth rivets	100
Steel, vitrified, spiral-riveted	90 - 100
Steel, corrugated	60
Tin	130
Vitrified Clays	110
Wood Stave	110 - 120

Pressure Head

A pressure difference of 5 psi (lbf/in^2) is equivalent to

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 62.4 (lb/ft^3) = 11.6 ft of water

5 (lbf/in^2) 12 (in/ft) 12 (in/ft) / 847 (lb/ft^3) = 0.85 ft of mercury

When specific weight of water is 62.4 (lb/ft^3) and specific weight of mercury is 847 (lb/ft^3).

Heads at different velocities can be taken from the table below:

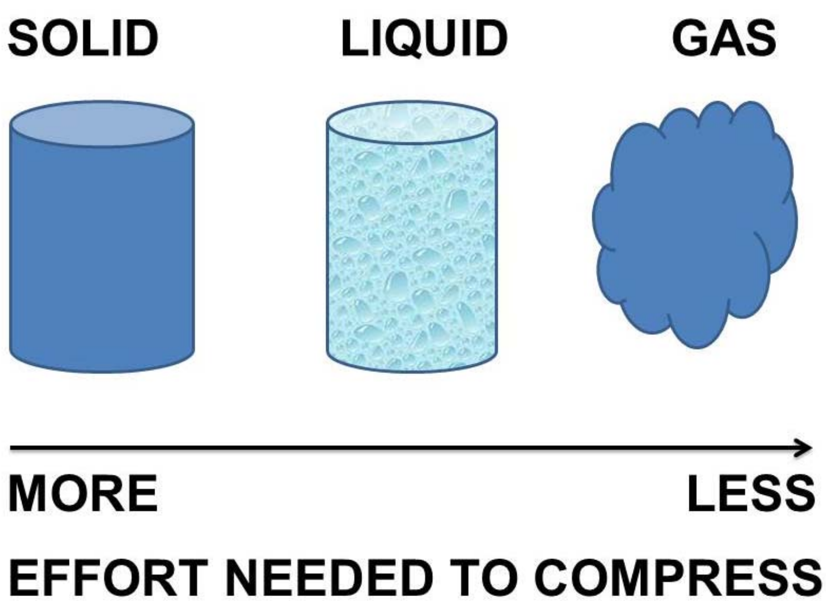
Velocity (ft/sec)	Head Water (ft)
0.5	0.004
1.0	0.016
1.5	0035
2.0	0.062
2.5	0.097
3.0	0.140
3.5	0.190
4.0	0.248
4.5	0.314
5.0	0.389
5.5	0.470
6.0	0.560
6.5	0.657
7.0	0.762
7.5	0.875
8.0	0.995
8.5	1.123
9.0	1.259
9.5	1.403
10.0	1.555
11.0	1.881
12.0	2.239
13.0	2.627
14.0	3.047
15.0	3.498
16.0	3.980
17.0	4.493
18.0	5.037
19.0	5.613
20.0	6.219
21.0	6.856
22.0	7.525

1 ft (foot) = 0.3048 m = 12 in = 0.3333 yd.

Thermal Properties of Water

Temperature - *t* - (^oC)	Absolute pressure - *p* - (kN/m^2)	Density - *ρ* - (kg/m^3)	Specific volume - *v* - ($m^3/kgx10^{-3}$)	Specific Heat - c_p - (kJ/kgK)	Specific entropy - *e* - (kJ/kgK)
0	0.6	1000	100	4.217	0
5	0.9	1000	100	4.204	0.075
10	1.2	1000	100	4.193	0.150
15	1.7	999	100	4.186	0.223
20	2.3	998	100	4.182	0.296
25	3.2	997	100	4.181	0.367
30	4.3	996	100	4.179	0.438
35	5.6	994	101	4.178	0.505
40	7.7	991	101	4.179	0.581
45	9.6	990	101	4.181	0.637
50	12.5	988	101	4.182	0.707
55	15.7	986	101	4.183	0.767
60	20.0	980	102	4.185	0.832
65	25.0	979	102	4.188	0.893
70	31.3	978	102	4.190	0.966
75	38.6	975	103	4.194	1.016
80	47.5	971	103	4.197	1.076
85	57.8	969	103	4.203	1.134
90	70.0	962	104	4.205	1.192
95	84.5	962	104	4.213	1.250
100	101.33	962	104	4.216	1.307
105	121	955	105	4.226	1.382
110	143	951	105	4.233	1.418
115	169	947	106	4.240	1.473
120	199	943	106	4.240	1.527
125	228	939	106	4.254	1.565
130	270	935	107	4.270	1.635
135	313	931	107	4.280	1.687
140	361	926	108	4.290	1.739
145	416	922	108	4.300	1.790
150	477	918	109	4.310	1.842
155	543	912	110	4.335	1.892
160	618	907	110	4.350	1.942

165	701	902	111	4.364	1.992
170	792	897	111	4.380	2.041
175	890	893	112	4.389	2.090
180	1000	887	113	4.420	2.138
185	1120	882	113	4.444	2.187
190	1260	876	114	4.460	2.236
195	1400	870	115	4.404	2.282
200	1550	863	116	4.497	2.329
220					
225	2550	834	120	4.648	2.569
240					
250	3990	800	125	4.867	2.797
260					
275	5950	756	132	5.202	3.022
300	8600	714	140	5.769	3.256
325	12130	654	153	6.861	3.501
350	16540	575	174	10.10	3.781
360	18680	526	190	14.60	3.921



Viscosity Converting Chart

The viscosity of a fluid is its resistance to shear or flow, and is a measure of the fluid's adhesive/ cohesive or frictional properties. This arises because of the internal molecular friction within the fluid producing the frictional drag effect. There are two related measures of fluid viscosity which are known as **dynamic** and **kinematic** viscosity.

Dynamic viscosity is also termed "**absolute viscosity**" and is the tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid.

Centipoise (CPS) Millipascal (mPas)	Poise (P)	Centistokes (cSt)	Stokes (S)	Saybolt Seconds Universal (SSU)
1	0.01	1	0.01	31
2	0.02	2	0.02	34
4	0.04	4	0.04	38
7	0.07	7	0.07	47
10	0.1	10	0.1	60
15	0.15	15	0.15	80
20	0.2	20	0.2	100
25	0.24	25	0.24	130
30	0.3	30	0.3	160
40	0.4	40	0.4	210
50	0.5	50	0.5	260
60	0.6	60	0.6	320
70	0.7	70	0.7	370
80	0.8	80	0.8	430
90	0.9	90	0.9	480
100	1	100	1	530
120	1.2	120	1.2	580
140	1.4	140	1.4	690
160	1.6	160	1.6	790
180	1.8	180	1.8	900
200	2	200	2	1000
220	2.2	220	2.2	1100
240	2.4	240	2.4	1200
260	2.6	260	2.6	1280
280	2.8	280	2.8	1380
300	3	300	3	1475
320	3.2	320	3.2	1530

340	3.4	340	3.4	1630
360	3.6	360	3.6	1730
380	3.8	380	3.8	1850
400	4	400	4	1950
420	4.2	420	4.2	2050
440	4.4	440	4.4	2160
460	4.6	460	4.6	2270
480	4.8	480	4.8	2380
500	5	500	5	2480
550	5.5	550	5.5	2660
600	6	600	6	2900
700	7	700	7	3380
800	8	800	8	3880
900	9	900	9	4300
1000	10	1000	10	4600
1100	11	1100	11	5200
1200	12	1200	12	5620
1300	13	1300	13	6100
1400	14	1400	14	6480
1500	15	1500	15	7000
1600	16	1600	16	7500
1700	17	1700	17	8000
1800	18	1800	18	8500
1900	19	1900	19	9000
2000	20	2000	20	9400
2100	21	2100	21	9850
2200	22	2200	22	10300
2300	23	2300	23	10750
2400	24	2400	24	11200

Various Flow Section Channels and their Geometric Relationships:

Area, wetted perimeter and hydraulic diameter for some common geometric sections like

- rectangular channels
- trapezoidal channels
- triangular channels
- circular channels.

Rectangular Channel

Flow Area

Flow area of a rectangular channel can be expressed as

A = b h (1)

where

A = flow area (m^2, in^2)

b = width of channel (m, in)

h = height of flow (m, in)

Wetted Perimeter

Wetted perimeter of a rectangular channel can be expressed as

P = b + 2 h (1b)

where

P = wetted perimeter (m, in)

Hydraulic Radius

Hydraulic radius of a rectangular channel can be expressed as

R_h *= b h / (b + 2 y) (1c)*

where

R_h *= hydraulic radius (m, in)*

Trapezoidal Channel

Flow Area

Flow area of a trapezoidal channel can be expressed as

A = (a + z h) h (2)

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a trapezoidal channel can be expressed as

$P = a + 2 h (1 + z^2)^{1/2}$ (2b)

Hydraulic Radius

Hydraulic radius of a trapezoidal channel can be expressed as

$R_h = (a + z h) h / a + 2 h (1 + z^2)^{1/2}$ (2c)

Triangular Channel

Flow Area

Flow area of a triangular channel can be expressed as

$A = z h^2$ *(3)*

where

z = see figure above (m, in)

Wetted Perimeter

Wetted perimeter of a triangular channel can be expressed as

$P = 2 h (1 + z^2)^{1/2}$ *(3b)*

Hydraulic Radius

Hydraulic radius of a triangular channel can be expressed as

$R_h = z h / 2 (1 + z^2)^{1/2}$ *(3c)*

Circular Channel

Flow Area

Flow area of a circular channel can be expressed as

$A = D^2/4 (\alpha - \sin(2 \alpha)/2)$ *(4)*

where

D = diameter of channel

$\alpha = \cos^{-1}(1 - h/r)$

Wetted Perimeter

Wetted perimeter of a circular channel can be expressed as

$P = \alpha D$ *(4b)*

Hydraulic Radius

Hydraulic radius of a circular channel can be expressed as

$R_h = D/8 [1 - \sin(2 \alpha) / (2 \alpha)]$ *(4c)*

Velocity Head: Velocity head can be expressed as

$h = v^2/2g$ *(1)*

where

v = velocity (ft, m)

g = acceleration of gravity $(32.174 ft/s^2, 9.81 m/s^2)$

Heads at different velocities can be taken from the table below:

Velocity - *v* - (ft/sec)	Velocity Head - $v^2/2g$ - (ft Water)
0.5	0.004
1.0	0.016
1.5	0035
2.0	0.062
2.5	0.097
3.0	0.140
3.5	0.190
4.0	0.248
4.5	0.314
5.0	0.389
5.5	0.470
6.0	0.560
6.5	0.657
7.0	0.762
7.5	0.875
8.0	0.995
8.5	1.123
9.0	1.259
9.5	1.403
10.0	1.555
11.0	1.881
12.0	2.239
13.0	2.627
14.0	3.047
15.0	3.498
16.0	3.980
17.0	4.493
18.0	5.037
19.0	5.613
20.0	6.219
21.0	6.856
22.0	7.525

Some Commonly used Thermal Properties for Water

- Density at 4 ^oC - 1,000 kg/m^3, 62.43 Lbs./Cu.Ft., 8.33 Lbs./Gal., 0.1337 Cu.Ft./Gal.
- Freezing temperature - 0 ^oC
- Boiling temperature - 100 ^oC
- Latent heat of melting - 334 kJ/kg
- Latent heat of evaporation - 2,270 kJ/kg
- Critical temperature - 380 - 386 ^oC
- Critical pressure - 23.520 kN/m^2
- Specific heat capacity water - 4.187 kJ/kgK
- Specific heat capacity ice - 2.108 kJ/kgK
- Specific heat capacity water vapor - 1.996 kJ/kgK
- Thermal expansion from 4 ^oC to 100 ^oC - $4.2x10^{-2}$
- Bulk modulus elasticity - 2,068,500 kN/m^2

Reynolds Number

Turbulent or laminar flow is determined by the dimensionless **Reynolds Number.**

The Reynolds number is important in analyzing any type of flow when there is substantial velocity gradient (i.e., shear.) It indicates the relative significance of the viscous effect compared to the inertia effect. The Reynolds number is proportional to inertial force divided by viscous force.

A definition of the Reynolds' Number:
The flow is

- **laminar** if Re < 2300
- **transient** if 2300 < Re < 4000
- **turbulent** if 4000 < Re

The table below shows Reynolds Number for one liter of water flowing through pipes of different dimensions:

Pipe Size										
(inches)	1	1 ?	2	3	4	6	8	10	12	18
(mm)	25	40	50	75	100	150	200	250	300	450
Reynolds number with **one (1) liter/min**	835	550	420	280	210	140	105	85	70	46
Reynolds number with **one (1) gal/min**	3800	2500	1900	1270	950	630	475	380	320	210

Linear Motion Formulas

Velocity can be expressed as (velocity = constant):

$v = s / t$ (1a)

where
v = velocity (m/s, ft/s)
s = linear displacement (m, ft)
t = time (s)

Velocity can be expressed as (acceleration = constant):
$v = V_0 + a\ t$ (1b)

where
V_0 = linear velocity at time zero (m/s, ft/s)

Linear displacement can be expressed as (acceleration = constant):
$s = V_0\ t + 1/2\ a\ t^2$ (1c)

Combining 1a and 1c to express velocity
$v = (V_0^2 + 2\ a\ s)^{1/2}$ *(1d)*

Velocity can be expressed as (velocity variable)
$v = ds / dt$ (1f)

where
ds = change of displacement (m, ft)
dt = change in time (s)

Acceleration can be expressed as
$a = dv / dt$ (1g)

where
dv = change in velocity (m/s, ft/s)

Water - Dynamic and Kinematic Viscosity

Dynamic and Kinematic Viscosity of Water in Imperial Units (BG units):

Temperature *- t -* *(°F)*	Dynamic Viscosity *- μ -* *10^{-5} (lbs./ft^2)*	Kinematic Viscosity *- ν -* *10^{-5} (ft^2/s)*
32	3.732	1.924
40	3.228	1.664
50	2.730	1.407
60	2.344	1.210
70	2.034	1.052
80	1.791	0.926
90	1.500	0.823
100	1.423	0.738
120	1.164	0.607
140	0.974	0.511
160	0.832	0.439
180	0.721	0.383
200	0.634	0.339
212	0.589	0.317

Dynamic and Kinematic Viscosity of Water in SI Units:

Temperature *- t -* *(°C)*	Dynamic Viscosity *- μ -* *10^{-3} (N.s/m^2)*	Kinematic Viscosity *- ν -* *10^{-6} (m^2/s)*
0	1.787	1.787
5	1.519	1.519
10	1.307	1.307
20	1.002	1.004
30	0.798	0.801
40	0.653	0.658
50	0.547	0.553
60	0.467	0.475
70	0.404	0.413
80	0.355	0.365
90	0.315	0.326
100	0.282	0.294

Water and Speed of Sound

Speed of sound in water at temperatures between 32 - 212°F (0-100°C) - imperial and SI units
Speed of Sound in Water - in imperial units (BG units)

Temperature - *t* - (°F)	Speed of Sound - *c* - (ft/s)
32	4,603
40	4,672
50	4,748
60	4,814
70	4,871
80	4,919
90	4,960
100	4,995
120	5,049
140	5,091
160	5,101
180	5,095
200	5,089
212	5,062

Speed of Sound in Water - in SI units

Temperature - *t* - (°C)	Speed of Sound - *c* - (m/s)
0	1,403
5	1,427
10	1,447
20	1,481
30	1,507
40	1,526
50	1,541
60	1,552
70	1,555
80	1,555
90	1,550
100	1,543

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