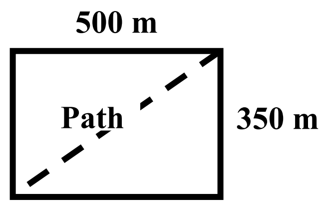
SFTY 470

Advanced Occupational Safety and Health Technology

<u>REVIEW OF SAFETY MATH</u>

TRIGONOMETRIC FUNCTIONS

Example 1: A field is 0.5 kilometers long and 350 meters wide. You need to install a pathway across the field diagonally from corner to corner. What is the length of the pathway?



Solve: <u>Method 1</u>

a = 350 m   b = 500 m

$c^2 = a^2 + b^2$ (Pythagorean theorem)

$a^2 = 122{,}500$

$b^2 = 250{,}000$

$c^2 = 122{,}500 + 250{,}000 = 372{,}000$

c = 610.

<u>Method 2</u>

tan A = a / b = 350 / 500 = 0.7

using the Trig Table: A = 35^o

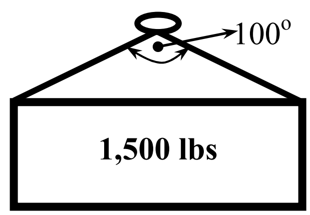
sin 35^o = a / c

0.5736 = 350 / c

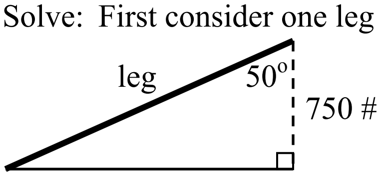
c = 350 / 0.5736 = 610.18

The pathway is <u>610 meters</u> long.

Example 2: A crane is picking up a block weighing 1,500 pounds with a two-legged sling rated for 2,000 pounds. When attached to the block the sling legs form an angle at the lift ring of 100^o. Can this sling safely life the load? What rating does the "minimum" sling need to be (to a hundred pounds)?



Solve: First consider one leg of the sling. Drop a line vertically down from the lift ring creating a right triangle consisting of the vertical line, the top of the block, and the sling leg. The angle at the lift ring is 50^o (half of 100^o) and the adjacent side (the vertical line) has a value of 750 lbs (half of 1,500 lbs).



cos A = adjacent / hypotenuse

cos 50^o = 750 / leg   0.64279 = 750 / leg

leg = 750 / 0.64279   leg = 1,166.77

2 legs = 2,234 lbs   the 2,000 pound sling will not work.

Minimum sling rating for the load is 2,300 lbs.

QUADRATIC EQUATION

http://www.chem.tamu.edu/class/fyp/mathrev/mr-quadr.html

Form: $ax^2 + bx + c = 0$

Example: $6x^2 + 2x - 4 = 0$

Solve:

$$x_1, x_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Substitute:

$$x_1, x_2 = \frac{-2 \pm \sqrt{2^2 - (4 \bullet 6 \bullet -4)}}{2 \bullet 6}$$

Simplify:

$$x_1, x_2 = \frac{-2 \pm \sqrt{4 - (-96)}}{12}$$

$$x_1, x_2 = \frac{-2 \pm \sqrt{100}}{12}$$

$$x_1, x_2 = \frac{-2 \pm 10}{12}$$

$$x_1, x_2 = \frac{8, -12}{12}$$

Answer: $\underline{x_1 = 0.667}$, $\underline{x_2 = -1}$

GEOMETRIC FORMULAS

Circle $C = \pi D$ where: C = circumference A = area

$A = \pi r^2$ D = diameter r = radius

Example: A circle has a radius of 3 in. What is the circumference and area?

Solve: $C = \pi \bullet (2 \bullet 3) = 3.14 \bullet 6 = \underline{18.84 \text{ in}}$.

$A = \pi \bullet 3^2 = 3.14 \bullet 9 = \underline{28.26 \text{ in}^2}$

Sphere $S = 4\pi r^2$ where: S = surface area V = volume

$V = (4/3)\, \pi r^3$ r = radius

Example: A sphere has a diameter of 10 cm. What is the surface area and volume?

Solve: $r = 1/2\, D = 10/2 = 5$ cm

$S = 4 \bullet \pi \bullet 5^2 = 4 \bullet 3.14 \bullet 25 = \underline{314 \text{ cm}^2}$.

$V = (4/3) \bullet \pi \bullet 5^3 = 1.33 \bullet 3.14 \bullet 125 = \underline{2{,}189.45 \text{ cm}^3}$.

Trapezoid: $A = 1/2\, (b_1 + b_2)\, h$ where: A = area b_1, b_2 = sides

h = height

Example: What is the area of a trapezoid shaped field that is 110 meters deep with one side 75 meters and its opposite side 95 meters?

Solve: $A = 1/2\, (b_1 + b_2)\, h = 1/2 \bullet (75 + 95) \bullet 110 = (170 / 2) \bullet 110 = \underline{9{,}350 \text{ m}^2}$ (or 0.935 hectare)

Answers above <u>without units</u> would be considered <u>wrong</u>.

STATISTICS

Standard Deviation

http://mathworld.wolfram.com/StandardDeviation.html

$$s = \sqrt{\frac{\Sigma (x^2)}{N - 1}} \qquad (x = X - \overline{X}) \qquad \sigma = \sqrt{\frac{\Sigma (x^2)}{N}}$$

where: s = standard deviation for a sample x = value

σ = standard deviation for total population N = number of values

Example: Find the standard deviation for the following values: 2, 5, 3, 7, 6, 4. What is the standard deviation if the series is the total population?

Solve: N = 6

Create a Table

X	$\overline{X}$	x	x^2	
2	4.5	-2.5	6.25	
5	4.5	0.5	0.25	
3	4.5	-1.5	2.25	
7	4.5	2.5	6.25	
6	4.5	1.5	2.25	
4	4.5	-0.5	0.25	
27			17.50	Sum

$\overline{X} = 27/6$

Substitute: For Sample For Total Population

$$s = \sqrt{\frac{17.5}{5}} \qquad \sigma = \sqrt{\frac{17.5}{6}}$$

Answer: $s = \sqrt{3.5} = \underline{1.87}$ $\sigma = \sqrt{2.92} = \underline{1.71}$

Linear Regression

http://www.curvefit.com/linear_regression.htm

$y = mx + b$ where: m = slope

b = y-intercept

$$r = \frac{N\Sigma(xy) - (\Sigma(x) \bullet \Sigma(y))}{\sqrt{[N\Sigma(x^2) - N\Sigma(x)^2] \bullet [N\Sigma(y^2) - N\Sigma(y)^2]}}$$

Example: Find the slope, y-intercept, and correlation coefficient for the following points:

x	y	x	y	x	y	x	y	x	y
6.5	5	6	3	7	6	3	1	6	2.5
7.5	3.5	3.5	3	2	0.5	8.5	6		

x	x^2	**y**	y^2	xy
6.5	2.25	**5**	4	3
6	1	**3**	0	0
7	4	**6**	9	6

3	4	**1**	4	4
6	1	**2.5**	0.25	-0.5
7	4	**3.5**	0.25	1
3.5	2.25	**3**	0	0
2	9	**0.5**	6.25	7.5
4	1	**2.5**	0.25	0.5
45	28.5	**27**	24	21.5

$\Sigma(x)^2 = 2{,}025$ $\Sigma(y)^2 = 729$

$N = 9$

Substitute:

$$m = \frac{N\,\Sigma(xy) - \Sigma(x)\,\Sigma(y)}{N\,\Sigma(x^2) - \Sigma(x)^2} \qquad m = \frac{(9 \bullet 156.5) - (45 \bullet 27)}{(9 \bullet 253.5) - 2{,}025}$$

$$m = \frac{1{,}408.5 - 1{,}215}{2{,}281.5 - 2{,}025} \qquad m = \frac{193.5}{256.5}$$

$m = \underline{0.754}$

Substitute:

$$b = \frac{\Sigma(y) - m\,\Sigma(x)}{N} \qquad b = \frac{27 - 0.754 \bullet 45}{9}$$

$$b = \frac{27 - 33.95}{9} \qquad b = \frac{-6.95}{9}$$

$b = \underline{-0.772}$

Line is: $y = 0.754\,x - 0.772$

Correlation Coefficient

http://www.uwsp.edu/psych/stat/7/correlat.htm#I2

$$r = \frac{N\,\Sigma(xy) - (\Sigma(x) \bullet \Sigma(y))}{\sqrt{[N\,\Sigma(x^2) - \Sigma(x)^2] \bullet [N\,\Sigma(y^2) - \Sigma(y)^2]}}$$

Substitute:

$$r = \frac{(9 \bullet 156.5) - (45 \bullet 27)}{\sqrt{[(9 \bullet 253.5) - (45^2)] \bullet [(9 \bullet 105) - (27^2)]}}$$

$$r = \frac{(1{,}408.5) - (1{,}215)}{\sqrt{[(2{,}281.5) - (2{,}025)] \bullet [(945) - (729)]}}$$

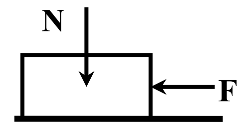
$$r = \frac{193.5}{\sqrt{[256.5] \bullet [216]}} \qquad r = \frac{193.5}{\sqrt{55{,}404}}$$

$$r = \frac{193.5}{235.4} \qquad r = \underline{0.822}$$

MECHANICS

http://tutor4physics.com/formulas.htm

Friction



$F = \mu N$ Where F = force parallel to the plane

N = force normal to the plane

μ = coefficient of friction

Sample of Coefficients of Friction

Material	Static μ_s	Kinetic μ_k
Steel on Steel	0.74	0.57k
Aluminum on Steel	0.61	0.47
Copper on Steel	0.53	0.36
Rubber on Concrete	1.0	0.8
Wood on Wood	0.25-0.5	0.2

Example 1: A 100 pound aluminum block rests on a steel surface. What force will it take to start the block moving? What force will it take to keep the block moving? (Assume constant acceleration.)

$$F = \mu N$$

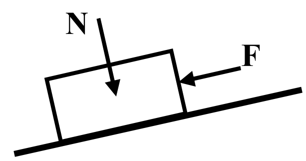
Static ($\mu_s = 0.61$)

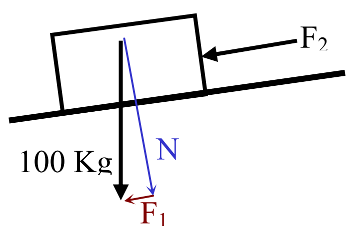
$F = 0.64 \bullet 100 =$ <u>64 lbs</u>

Kinetic ($\mu_k = 0.47$)

$F = 0.47 \bullet 100 =$ <u>47 lbs</u>

Example 2: A 100 Kg copper block rests on a 15° steel ramp. What force will it take to start the block moving down the ramp? What force will it take to start the block moving up the ramp?





$\sin 15^o = F_1 / 100$ $F_1 = \sin 15^o \bullet 100$ $F_1 = 0.2588 \bullet 100 = 25.9$ Kg

$\cos 15 = N / 100$ $N = \cos 15^o \bullet 100$ $N = 0.9659 \bullet 100 = 96.6$ Kg

μ_s copper on steel = 0.53

$F = \mu N$ $F_T = 0.53 \bullet 96.6 = 51.2$ Kg = Total force need to start the block moving.

Moving down the ramp
F_1 works with you

Moving up the ramp
F_1 works against you

$F_2 = 51.2 - 25.9 = \underline{25.3 \text{ Kg}}$ $\quad\quad$ $F_2 = 51.2 + 25.9 = \underline{77.1 \text{ Kg}}$

Gravitational Potential Energy

P.E. = mgh where: P.E. = Potential Energy m = mass
G = acceleration of gravity h = height

Example: What is the potential of a 5 pound box of nails setting on a 20 foot scaffold?

Solve: P.E. = mgh however: wt = mg

P.E. = wt • h = 5 • 20 = <u>100 foot-pounds</u>

Elastic Potential Energy

$$P.E. = \frac{kx^2}{2}$$

where: P.E. = Potential Energy
k = spring constant x = compression

Example: A heavy spring (k = 18.75 lbs / in) is compressed 6 in. What is the potential energy contained in the compressed spring?

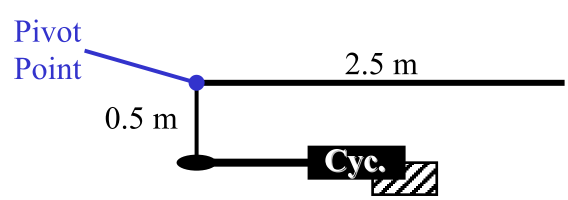
Solve: First change units to feet: 18.75 lbs / in • 12 in / ft = 225 lbs / ft
6 in = 0.5 ft

$P.E. = (k \bullet x^2) / 2 = (225 \bullet 0.5^2) / 2 = 27.12$ foot-pounds

Moment Arms – Couples

$F_1 D_1 = F_2 D_2$ where: F = force D = distance

Example: A tilt table has the needs to be able to hold 440 Kg. The table is 2.5 m wide and a hydraulic cylinder is attached to the table with a 0.5 m lever arm. With a safety factor of two, what force must the hydraulic cylinder be able to excerpt?



Solve: $F_1 = 440$, $D_1 = 2.5$, $F_2 = ?$, $D_2 = 0.5$

$F_2 = (440 \bullet 2.5) / 0.5 = 2{,}200$ Kg

Safety factor of 2: a • 2 = <u>4,400 Kg</u>

(Since the problem does not address it you must assume the full load at the edge of the table.)

Velocity

$v = v_0 + at$ where: v = velocity (final) t = time

$v^2 = v_0^2 + 2as$ $\quad$ v_0 = initial velocity s = distance

a = acceleration

Example 1: A truck is driving the Interstate at 60 mph. To pass another truck the driver accelerates at 10 ft/sec for 5 seconds. How fast is the truck going after the 5 seconds? (1 mph = 1.467 ft/sec)

Solve: $60 \text{ mph} \bullet 1.467 = 88$ ft/sec.

$v = v_0 + at = 88 + (5 \bullet 5) = 88 + 25 = 113$ ft/sec.

113 ft /sec / 1.467 = <u>77 mph</u>.

Example 2: During an argument over time spent at home, a 5.5 kg bowling ball get tossed out of a 3rd story townhouse window. The window is 6 meters above ground level. How fast was the bowling ball traveling when it hit the ground?

Solve: Acceleration due to gravity = 9.8 m / sec^2 $v_0 = 0$

$v^2 = v_0^2 + 2as = 0 + (2 \bullet 9.8 \bullet 6) = 117.6$

$v = (117.6)^{0.5}$ = <u>10.8 m / sec.</u>

Force, Momentum, and Work

$p = mv$	where: p = momentum	m = mass	v = velocity
$F = ma$	F = force	a = acceleration	
$W = Fs$	W = work	s = distance	

Example 1: A 2,000 pound car is traveling at 45 mph. What is its momentum?

Solve: m = weight / gravity = 2,000 / 32.2 = 62.1 lbs sec^2 / ft

Convert v into ft/sec: $1.467 \bullet 45 = 66$ ft / sec

$p = mv = 62.1 \bullet 66 =$ <u>4,098.6 lbs-sec</u>

Example 2: Same 2,000 pound car is traveling at 45 mph and then decelerates at a rate of 3 ft / sec^2. What is the braking force that is applied?

Solve: m = 62.1 lbs sec^2 / ft

$F = ma = 62.1 \bullet 3 =$ <u>186.3 lbs</u>.

Example 3: A student has 5 kg of books to carry to class. The distance from the parking lot to the classroom is 220 m. How much work is preformed?

Solve: $W = Fs = 5 \bullet 220 = 1{,}100$ Kg-m (needs to be in joules [1 joule = 9.806 Kg-m])

1,100 / 9.806 = <u>112.2 joules</u>

Kinetic Energy

$$K.E. = \frac{mv^2}{2}$$

where: K.E. = kinetic energy
m = mass
v = velocity

Example: What is the kinetic energy of a 2,000 pound car is traveling at 45 mph?

Solve: m = 62.1 lbs sec^2 / ft v = 66 ft / sec

K.E. = $(62.1 \bullet 66^2) / 2$ = <u>135,254 lbs</u>

HEAT STRESS

http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html

WBGT = 0.7 WB + 0.3 GT   (Indoors; no solar heat load)

WBGT = 0.7 WB + 0.2 BT + 0.1 DB   (Outdoors; with solar heat load)

where: WBGT = Wet Bulb Globe Temperature Index
WB = (Nature) Wet-Bulb Temperature
GT = Globe Temperature
DB = Dry-Bulb Temperature

VENTILATION

http://www.airhand.com/industrial-ventilation.asp

Air Movement

Q = AV where: Q = volume of air moving at a specific point
A = area at a specific point
V = velocity of air moving at a specific point

Example 1: The capture velocity of air at the back of a paint booth needs to be 100 ft/min. The filter opening for the exhaust air measures 18 by 24 inches. What volume of air needs to be moved to meet the capture velocity?

Solve: $Q = (1.5 \bullet 2) \bullet 100 = \underline{300\ ft^3/min}$.

Example 2: What is the velocity of air 12 cm from the opening of a 24 cm diameter duct, given the volume of air being moved is 20 m^3/sec. [An IH fact: at 50% of the diameter, the velocity of air is only 30% of that at the opening.]

Solve: Think of the end of a pipe. If you pull a suction through the air entering the pipe comes from all directions. It has been found the air entering the pipe come from the surface a sphere x distance from the opening.

Now surface area of a sphere is $A = 4\ \pi\ x2 = 4 \bullet 3.14 \bullet (0.24)^2 = 0.72\ m^2$

$Q = AV$ or $V = Q / A$

$V = 20 / 0.72 = 27.78$ m/sec.

@ 12 cm only 30% effective: $V_{12} = .3 \bullet 27.78 = \underline{8.33\ m/sec}$.

Velocity Pressure

$V = 4005 \sqrt{VP}$ where: V = velocity
VP = velocity pressure

Example: A manometer is used to measure the pressure at a point in a duct. It measured 1.15 in H_2O. What is the air velocity at the point? (This assumes a standard day.)

Solve: $V = 4005\ sqr(VP) = 4005 \bullet (1.15)^{0.5} = \underline{4{,}295\ ft/min}$.

Hoods

$V = 4005\ C_e \sqrt{SP_h}$ where: V = velocity

C_e = coefficient of entry for a hood

SP_h = hood static pressure

Example: A hood in a plating shop has a 0.65 coefficient of entry. The static pressure measured at the face of the hood is 1.15 in H_2O. What is the air velocity at the face? (This assumes a standard day.)

Solve: $V = 4005\ C_e\ sqr(SP_h) = 4005 \bullet 0.65 \bullet (1.15)^{0.5} = \underline{2{,}792\ ft/min}$.

$TP = SP + VP$ where: TP = total pressure

SP = static pressure

VP = velocity pressure

RADIATION

http://www.st-andrews.ac.uk/services/safety/webpages/radiation/6.html#6.1.1

$$I_2 = I_1 \frac{(d_1)^2}{(d_2)^2}$$

where: I_1 = radiation exposure at d_1

I_2 = radiation exposure at d_2

d_1, d_2 = distance from radiation source

Example: A radiation source produces a 500 mR at 18 inches. What is the exposure at 10 ft?

Solve: $I_2 = 500 \bullet (1.52 / 102) = 500 \bullet (2.25 / 100) = \underline{11.25\ mR}$.

$S \approx 6CE$ where: S = R/hr (at 1 foot)

C = strength of source in curies

E = energy of gamma-radition

Example: What radiation read would be expected at a distance of 1 foot from an unshielded 100 millicurie cobalt-60 source? [Given E = 2.5 MeV]

Solve: $S \approx 6 \bullet 0.1 \bullet 2.5 = \underline{1.5\ R/hr}$.

ENGINEERING ECONOMICS

Future and Present Value of Money

http://www.investopedia.com/articles/03/082703.asp

$F = P(1 + i)^n$ where: F = future value; P = present value (principle)

$P = F(1 + i)^{-n}$ i = interest; n = number of payments (term)

Example 1: You invest \$1,000 today at 10% per year for 10 years compounded monthly. What is the value of you investment at the end of the10 years?

Solve: Compounded monthly: $i = 0.1 / 12 = 0.00833$ $n = 10 \bullet 12 = 120$

$$F = P(1 + i)^n = 1{,}000 \bullet (1 + 0.00833)^{120} = 1{,}000 \bullet 2.707 = \underline{\$2{,}707}$$

Example 2: Congratulations you won the lottery with a total value of \$15 million paid in equal yearly payments over 25 years. Assuming an interest 4% per year how much is your winnings worth in today's money?

Solve: $P = F(1 + i)^{-n} = 15{,}000{,}000 \bullet (1 + 0.04)^{-25} = 15{,}000{,}000 \bullet 0.2953 = \underline{\$4{,}430{,}000}$

NOISE

Sound Power Levels

http://www.ccohs.ca/oshanswers/phys_agents/noise_basic.html

$$L_w = 10 \log_{10} \frac{W}{W_0}$$

where: L_w = sound power level in dB

W = sound power measured in watts

W_0 = reference sound power = 10^{-12} watt (picowatt)

Example: A noise source produces 8 micro Watts (μW). What is the sound level in dB?

Solve: $L_w = 10 \log_{10} (0.000008 / 10^{-12}) = 10 \log_{10} (8 \bullet 106) = 10 \bullet 6.9 = \underline{69 \text{ dB}}$.

Sound Pressure Levels

http://www.sfu.ca/sonic-studio/handbook/Sound_Pressure_Level.html

$$L_p = 20 \log_{10} \frac{p}{p_0} \text{ dB}$$

where: L_P = sound pressure level

p = sound pressure measured in Pa

p_0 = reference sound pressure = $2 \bullet 10^{-5}$ Pa (20 μPa)

Example: A typical gasoline-powered lawn mower produces 1 Pa of sound pressure. What is the sound level in dB?

Solve: $L_p = 20 \log_{10} [1 / (2 \bullet 10^{-5})] = 20 \log_{10} (50{,}000) = 20 \bullet 4.7 = \underline{94 \text{ dB}}$.

Time Weighted Average

http://www.osha-slc.gov/dts/osta/otm/otm_iii/otm_iii_5.html

$$TWA_8 = [(dB_1 \bullet t_1) + (dB_2 \bullet t_2) + \ldots + (dB_n \bullet t_n)] / 8$$

where: $dB_1, dB_2, \ldots dB_n$ = sound in dB at $t_1, t_2, \ldots t_n$

$t_1, t_2, \ldots t_n$ = time (duration)

Example: An employee performs several tasks during the course of his / her working day. The duration and the noise level associated with each task are listed below. What is the TWA the worker experiences during the shift?

Exposure Level

a) Operation of pneumatic hammer. 1 hr. 100 dBa
b) Operation of surface grader. 4 hrs. 91 dBa
c) Operation of street cleaner. 2 hrs. 93 dBa
d) Using sand blaster. 1/3 hrs 112 dBa
e) Operating riding mower. 2/3 hrs. 101 dBa

Solve: $TWA_8 = [(100 \bullet 1) + (91 \bullet 4) + (93 \bullet 2) + (112 \bullet 0.333) + (101 \bullet 0.667)] / 8$

$TWA_8 = [100 + 364 + 186 + 37.33 + 67.33] / 8 = 754.67 / 8 = \underline{94.3\text{ dBa}}$.

Reference Duration

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9736

$$T = \frac{8}{2^{[(L - 90) / 5]}}$$

where: T = Reference duration, (hour)
L = A-weighted sound level, (decibel)

Example: using the same exposures above, what is the reference duration for each?

Exposure Level

a) Operation of pneumatic hammer. 100 dBa
b) Operation of surface grader. 91 dBa
c) Operation of street cleaner. 93 dBa
d) Using sand blaster. 112 dBa
e) Operating riding mower. 101 dBa

Solve: $[(L – 90) / 5] = [(100 – 90) /5] = 2$

$T_{100} = 8 / 2^{[2]} = 8 / 4 = \underline{2\text{ hrs}}$.

Similarly $T_{91} = 8 / 2^{[0.2]} = 6.96$ hrs. $T_{93} = 8 / 2^{[0.6]} = 5.28$ hrs.

$T_{112} = 8 / 2^{[4.4]} = 0.38$ hrs. $T_{101} = 8 / 2^{[2.2]} = 1.74$ hrs.

Dose

http://www.oshanoise.com/osha_standard.html

$$D = \left[\frac{C_1}{T_1} + \frac{C_2}{T_2} + \dots + \frac{C_n}{T_n}\right] 100$$

where: $C_1, C_2, \dots C_n$ = exposure in dB
$T_1, T_2, \dots T_n$ = reference duration for $C_1, C_2, \dots C_n$

Example: An employee performs several tasks during the course of his / her working day. The duration and the noise level associated with each task are listed below:

Exposure Level

a) Operation of pneumatic hammer. 1 hr. 100 dBa
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d) Using sand blaster. 1/3 hrs 112 dBa
e) Operating riding mower. 2/3 hrs. 101 dBa

Solve: Use T values from precious example

$D = 100 \bullet [(100 / 2) + (91 / 6.96) + (93 / 5.28) + (112 / 0.38) + (101 / 1.74)]$

$D = 100 \bullet [50 + 13.07 + 17.61 + 294.7 + 58.05] = \underline{433.5\%}$

Decibel Difference ΔdB

http://www.sfu.ca/sonic-studio/handbook/Inverse-Square_Law.html

$$dB_1 - dB_0 = 20 \log_{10} \left[\frac{d_0}{d_1}\right]$$

where: dB_0 = noise exposure at d_0
dB_1 = noise exposure at d_1
d_0, d_1 = distance from noise source

Example: A noise source produces 112 dBa at 18 inches. What is the exposure at 10 ft?

Solve: $dB_1 = 112 + 20 \log_{10} (1.5 / 10) = 112 + 20 \log_{10} (0.15) = 112 + (20 \bullet -0.824) = \underline{95.5 \text{ dB}}$.

Time-weighted average (with the noise level constant over the entire shift)

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9736

$$TWA = 16.61 \log_{10} \left[\frac{D}{100}\right] + 90$$

where: D = dose (percent noise exposure)

Example: A disk jockey works at a disco and experiences 98 dBa constantly over the entire shift. What is the TWA?

Solve: First: T: $T_{98} = 8 / 2^{[(98-90)/5]} = 8 / 2^{[1.6]} = 8 / 3.03 = \underline{2.64 \text{ hrs}}$.

Next: D: $D = 100 \bullet (98 / 2.64) = 37.1\%$

Now $TWA = 16.61 \log_{10} (37.1 / 100) + 90 = (16.61 \bullet -0.43) + 90 = \underline{82.8 \text{ dBa}}$

ELECTRICITY

Ohm's Law

http://www.the12volt.com/ohm/ohmslaw.asp

$V = IR$ $P = VI$ and therefore $P = I^2R$

where: V = voltage in volts (V) I = current in amps (A)
R = resistance in ohms (Ω) P = power in watts (W)

Example 1: A lamp in your U.S. home has a resistance of 6 ohms. What current does it draw? And how much power does it use?

Solve: $I = V / R = 120 / 6 = \underline{20 \text{ amps}}$

$P = 20^2 \bullet 6 = 2{,}400$ watts or $P = 120 \bullet 20 = 2{,}400$ watts

Example 2: A lamp in your European home has a resistance of 6 ohms. What current does it draw? And how much power does it use?

Solve: $I = V / R = 240 / 6 = \underline{40 \text{ amps}}$

$P = 40^2 \bullet 6 = 9{,}600$ joules or $P = 240 \bullet 40 = 9{,}600$ joules

Total Resistance

$R_{series} = R_1 + R_2 + \cdots + R_n$

$$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

where: R_1, R_2, R_n = resistance in ohms (Ω)

Example: You have 4 resistors: 1 is 8 Ω, 2 are 10 Ω, and 1 is 15 Ω. What is the total resistance if they are wired in series? What is the total resistance if they are wired in parallel?

Solve: $R_{series} = 8 + 10 + 10 + 15 = \underline{43 \text{ ohms}}$

$1 / R_{parallel} = (1/8) + (1/10) + (1/10) + (1/15) = 0.125 + 0.1 + 0.1 + 0.067 = \underline{0.39 \text{ ohms}}$

$1 / R_{parallel} = 1 / 0.39$ $R_{parallel} = \underline{2.56 \text{ ohms}}$

CONCENTRATIONS OF VAPORS AND GASES

Conversion

http://www.ccohs.ca/oshanswers/chemicals/convert.html

$$ppm = \frac{mg / m^3 \bullet 24.45}{MW}$$

where: ppm = parts per million
MW = molecular weight
24.45 is a constant

Example: You have a sample of Hydrogen Sulfide, H_2S, with a reading of 43 mg / m^3? What is the equivalent parts per million? [MW of H_2S is 34.08 g/mol]

Solve: ppm = (43 24.45) / 34.08 = <u>30.85 ppm</u>

Mixtures

http://www.workplacegroup.net/article-exp-lmts-mixt.htm

$$TLV_m = \frac{1}{\left[\dfrac{f_1}{TLV_1} + \dfrac{f_2}{TLV_2} + \ldots + \dfrac{f_n}{TLV_n}\right]}$$

where: TLV_m, TLV_1, TLV_2, TLV_n = Threshold Limit Values

f_1, f_2, f_n = fraction of TLV

Example: Consider the measurements below from a workplace atmosphere that contained methyl ethyl ketone, toluene, methanol, and 2-butoxyethanol. All are identified as affecting the central nervous system.

Chemical	**TLV (8-hr TWA)**	**Measured Concentration (8-hr TWA)**
2-Butoxyethanol	20 ppm	5 ppm
Methanol	200 ppm	60 ppm
Methyl Ethyl Ketone	200 ppm	40 ppm
Toluene	50 ppm	20 ppm

Solve: First find the fraction of TLV for each chemical. f = measured / TLV

f_1, 2-Butoxyethanol = 5 / 20 = 0.25

f_2, Methanol = 60 / 200 = 0.3

f_3, Methyl Ethyl Ketone = 40 / 200 = 0.2

f_4, Toluene = 20 / 50 = 0.4

NOTE: No individual chemical exceeded its TLV. But, the sum of all f's is greater than 1. This indicates the mixture is above its TLV.

$TLV_m = 1 / [(0.25 / 20) + (0.3 / 200) + (0.2 / 200) + (0.4 / 50)]$

$TLV_m = 1 / [(0.0125) + (0.0015) + (0.001) + (0.008)] = 1 / 0.023$

$TLV_m = \underline{43.48\text{ ppm}}$

GAS LAWS

The Ideal Gas Law

http://www.chemistry.ohio-state.edu/betha/nealGasLaw/

$pV = nRT$ where: p = pressure in atm; V = volume in L; n = number of moles; T = temperature in K; $R = 0.0821\ L\ atm\ mol^{-1}\ K^{-1}$ (R = gas constant)

Example: Two moles of oxygen and one mole of nitrogen are contained in a cylinder with a volume of 10.0L at 298^{o}K. What is the total pressure? What is the partial pressure of oxygen?

Solve: $p = nRT / V = (n_{O2} + n_{N2})\, RT / V = [(2 + 1) \bullet 0.0821 \bullet 298] / 10 = \underline{7.34 \text{ atm}}$.

$p_{O2} = n_{O2}\, RT / V = [2 \bullet 0.0821 \bullet 298] / 10 = \underline{4.89 \text{ atm}}$.

Combined Gas Law

http://www.chemtutor.com/gases.htm

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

where: P_1, P_2 = pressure V_1, V_2 = volume
T_1, T_2 = temperature

Other Gas Laws: Boyle's Law: $P_1 V_1 = P_2 V_2$ Charles' Law: $V_1 / T_1 = V_2 / T_2$

Gay Lussac's Law: $P_1 / T_1 = P_2 / T_2$ Avogadro's Hypothesis: $V_1 / n_1 = V_2 / n_2$

Example 1: A gas occupies a volume of 20 L at a pressure of 5 atm and a temperature of 500K. What will the volume be if both the pressure is raised to 10 atm and temperature is changed to 250K?

Solve: $V_2 = P_1 V_1 T_2 / T_1 P_2$

$V_2 = (5 \bullet 20 \bullet 250) / (500 \bullet 10)$

$V_2 = 25{,}000 / 5{,}000 = \underline{5 \text{ L}}$

Given: P_1 = 5 atm P_2 = 10 atm
V_1 = 20 L V_2 = ?
T_1 = 500K T_2 = 250K

Example 2: A gas occupies a volume of 200 liters at a temperature of 300 K. What will be the volume if the temperature is changed to 1000 K?

Solve: $V_2 = V_1 T_2 / T_1$ (Charles' Law)

$V_2 = (200 \bullet 1000) / 300$

$V_2 = 25{,}000 / 5{,}000 = \underline{666.7 \text{ L}}$

Given: $\cancel{P_1}$ = $\cancel{P_2}$ =
V_1 = 200 L V_2 = ?
T_1 = 300K T_2 = 1000K

Example 3: A gas occupies a volume of 200 liters at a pressure of 2 atm. What will be the volume if both the pressure is raised to 10 atm?

Solve: $V_2 = P_1 V_1 / P_2$ (Boyle's Law)

$V_2 = (200 \bullet 2) / 10$

$V_2 = \underline{40 \text{ L}}$

Given: P_1 = 2 atm P_2 = 10 atm
V_1 = 200 L V_2 = ?
$\cancel{T_1}$ = $\cancel{T_2}$ =

RELIABILITY

Exponential Distribution

http://www.weibull.com/SystemRelWeb/analytical_life_predictions.htm

$P_f = 1 - R(t)$ where: P_f = probability of failure P_s = probability of success

$R(t) = e^{-\lambda\tau}$ $R(t)$ = reliability over time t

$P_f = (1 - P_s)$ λ = failure rate τ = time

Example: For a system, the probability of failure is 1 in 10,000 in one year (8,760 hours). What is the failure rate? What is the probability of success?

Solve: First: $P_f = 1 - R(t)$ $\quad R(t) = 1 - P_f = 1 - (1 / 10{,}000) = 0.9999$

Next: $R(t) = e^{-\lambda\tau}$ $\quad 0.9999 = e^{(-\lambda \bullet 8{,}760)}$

$\ln(0.9999) = -\lambda \bullet 8{,}760$ $\quad -0.0001 = -\lambda \bullet 8{,}760$

$\lambda = 0.0001 / 8{,}760 = \underline{0.00000001142}$

$P_f = (1 - P_s)$ $\quad P_s = 1 - P_f = 1 - (1 / 10{,}000) = \underline{0.9999}$

Molecular Weight – Selected Chemicals

msds jtbaker

	MW	sp.gr.	density
Aluminum = Al	26.981538		
Argon = Ar	39.948	1.378	1.784 g/litre
Acetone			
Carbon dioxide = CO_2	44.010	1.522	1.977 kg/m^3
Carbon Disulfide = CS_2	76.131		
Chlorine=Cl_2	70.906	2.473	3.214 g/litre
dichloroethylsulphide () =			
Ethyl Alcohol (ethanol, grain alcohol) = C_2H_5OH	46.069	0.789	
Fluorine = F_2	37.999	1.312	1.696g/L
Formaldehyde = HCHO			1.08
Gold = Au	196.96655		
Hexane (Hexanes) = C_6H_{14} ($CH_3(CH_2)_4CH_3$)	86.177		
Hydrochloric acid (Hydrogen Chloride) = HCl	36.461		
Hydrogen = H_2	2.01588	0.0696	0.08988 g/1
Krypton = Kr	83.8	2.899	
Methyl Ethyl Ketone (2-Butanone) = C_4H_8O ($CH_3COCH_2CH_3$)	72.107		
Methylene Chloride (Dichloromethane) = CH_2Cl_2	84.933		
Mercury = Hg	200.590		
Neon = Ne	20.1797	0.696	

Nitrogen = N_2	28.01348	0.967	
Oxygen - O_2	31.9988	1.105	
POTASSIUM CHLORATE (Potash chlorate; chloric acid) = $KClO_3$	122.549	2.3	
Silver = Ag	148.2276		
Sulphuric Acid (Oil of Vitriol) = H_2SO_4	98.073		
Toluene (Methylbenzene) = C_7H_8 (C_6H_5-CH_3)	92.140		
Trichloroethylene (Acetylene Trichloride) = C_2HCl_3	131.389		
Water = H_2O	18.015		
Xylenes (Dimethyl benzene) = C_8H_{10} ($C_6H_4(CH_3)_2$)	106.167		

Methane = CH_4 ≈ 75% CH_4 + 15% ethane (C_2H_6) + 5% propane (C_3H_8) + 5% butane (C_4H_{10})

MW = 16 0.554

dichloroethylsulphide Mustard gas is the common name given to 1,1-thiobis(2-chloroethane), a chemical warfare agent that is believed to have first been used near Ypres in Flanders on 12th July 1917. Its chemical formula is Cl-CH_2-CH_2-S-CH_2-CH_2-Cl

	72.11		36.46
	86.17		200.59
	92.14		122.549
$C_4H_8Cl_2S$	159.073		28.01
	106.16	NaCl	58.443
	84.93		20.18
Cl_2	70.906		32.00
	44.01	Pb	207.200
	76.14	Air	28.97

Formaldehyde properties 28.98

Xenon
Xe