

Advanced Sciences and Math for HSE Professionals

A Comprehensive Guide to Domain 1 Concepts

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Abstract

This document serves as a rigorous reconstruction of advanced HSE scientific principles, covering mathematics, mechanics, chemistry, electrical safety, industrial hygiene, ventilation, radiation, and engineering economy.

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Chapter 1

Mathematics Review

1.1 Fundamental Operations

1.1.1 Order of Operations (PEMDAS)

Mathematical calculations must follow a strict hierarchy to ensure accuracy:

1. Parentheses
2. Exponents
3. Multiplication & Division (Left to Right)
4. Addition & Subtraction (Left to Right)

1.1.2 Percentage Calculations

The fundamental rule for calculating percentages is relating a part to the whole.

$$\frac{\text{Part}}{\text{Total}} \times 100 = \% \quad (1.1)$$

Example: If the part is 60 and the total is 80:

$$\frac{60}{80} \times 100 = 75\%$$

1.1.3 Scientific and Engineering Notation

Large and small numbers are managed using powers of 10.

- **Scientific Notation:** One non-zero digit to the left of the decimal point (e.g., 3.57×10^4).
- **Engineering Notation:** The exponent is always a multiple of 3 (e.g., 35.7×10^3).

Table 1.1: SI Prefixes and Multipliers

Multiplier	Prefix	Symbol	Decimal
10^9	Giga	G	1,000,000,000
10^6	Mega	M	1,000,000
10^3	Kilo	k	1,000
10^{-1}	Deci	d	0.1
10^{-2}	Centi	c	0.01
10^{-3}	Milli	m	0.001
10^{-6}	Micro	μ	0.000001
10^{-9}	Nano	n	0.000000001

1.2 Geometry and Trigonometry

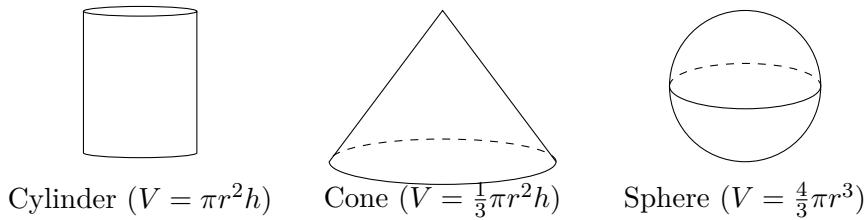


Figure 1.1: Common Geometric Shapes in HSE Calculations

1.2.1 Area and Volume

- **Circle Area:** $A = \pi r^2$ or $A = \frac{\pi d^2}{4}$
- **Cylinder Volume:** $V = \pi r^2 h$
- **Sphere Volume:** $V = \frac{4}{3} \pi r^3$
- **Cone Volume:** $V = \frac{1}{3} \pi r^2 h$

1.2.2 Trigonometry (SOH CAH TOA)

For a right-angled triangle with sides a (adjacent), b (opposite), and c (hypotenuse):

$$\begin{aligned}\sin \theta &= \frac{\text{Opposite}}{\text{Hypotenuse}} = \frac{b}{c} \\ \cos \theta &= \frac{\text{Adjacent}}{\text{Hypotenuse}} = \frac{a}{c} \\ \tan \theta &= \frac{\text{Opposite}}{\text{Adjacent}} = \frac{b}{a}\end{aligned}$$

Chapter 2

Physics and Mechanics

2.1 Newtonian Mechanics

2.1.1 Laws of Motion

1. **Inertia:** An object remains at rest or in uniform motion unless acted upon by a force.
2. **Force:** Force equals mass times acceleration ($F = ma$).
3. **Action-Reaction:** For every action, there is an equal and opposite reaction.

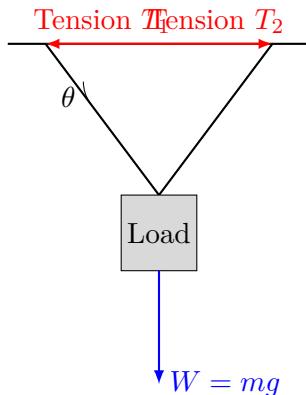


Figure 2.1: Force Vector Diagram: Sling Tension

Application: Sling Tension

When lifting a load using two slings at an angle, the tension increases as the angle to the horizontal decreases.

$$T = \frac{\text{Load per leg}}{\sin(\theta)}$$

2.2 Work, Energy, and Power

- **Work (W):** $W = F \cdot s$ (Force \times Distance). Measured in Joules.
- **Power (P):** Rate of doing work. $P = \frac{W}{t}$. Measured in Watts.

2.2.1 Energy Types

Energy Formulas

Kinetic Energy (KE): Energy of motion.

$$KE = \frac{1}{2}mv^2$$

Potential Energy (PE): Stored energy due to position.

$$PE = mgh$$

Elastic Potential Energy: Energy stored in a spring.

$$PE_{spring} = \frac{1}{2}kx^2$$

2.3 Fluid Mechanics (Hydraulics)

2.3.1 Pressure

Pressure is force per unit area ($P = F/A$).

- **Hydrostatic Pressure:** Pressure at depth h .

$$P = \rho gh$$

- **Standard Conversions:**

$$1 \text{ atm} = 14.7 \text{ psi} = 760 \text{ mmHg} = 33.9 \text{ ft } H_2O$$

2.3.2 Reynolds Number (Re)

Determines flow regime:

$$Re = \frac{\rho vd}{\mu}$$

- $Re < 2000$: Laminar Flow
- $2000 < Re < 4000$: Transitional Flow
- $Re > 4000$: Turbulent Flow

Chapter 3

Chemistry and Gas Laws

3.1 Basic Properties

3.1.1 Density and Specific Gravity

- **Density (ρ):** $\rho = \frac{\text{mass}}{\text{volume}}$
- **Specific Gravity (SG):** Ratio of substance density to water density.

$$SG = \frac{\rho_{\text{substance}}}{\rho_{\text{water}}}$$

3.2 Gas Laws

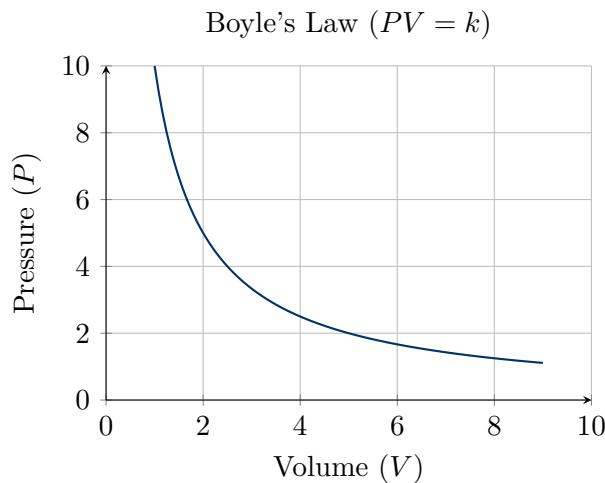


Figure 3.1: Inverse Relationship between Pressure and Volume (Isothermal)

3.2.1 Ideal Gas Law

$$PV = nRT$$

Where P =Pressure, V =Volume, n =Moles, R =Gas Constant, T =Temperature (Kelvin).

3.2.2 PPM Conversion

Converting concentration between mg/m^3 and ppm at NTP ($25^\circ C$, 1 atm):

$$\text{ppm} = \frac{mg/m^3 \times 24.45}{MW} \quad (3.1)$$

Chapter 4

Electrical Safety

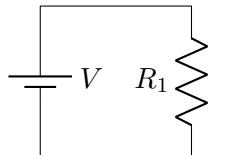
4.1 Fundamentals

4.1.1 Ohm's Law

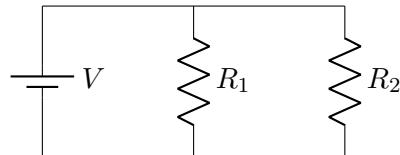
Relationship between Voltage (V), Current (I), and Resistance (R):

$$V = I \times R \quad (4.1)$$

4.2 Circuit Configurations



Simple Circuit



Parallel Circuit

Figure 4.1: Basic Circuit Diagrams

4.2.1 Circuits

- **Series Circuits:** $R_{total} = R_1 + R_2 + \dots + R_n$
- **Parallel Circuits:** $\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$

4.3 NFPA 70E Boundaries

1. **Arc Flash Boundary:** Distance where incident energy equals 1.2 cal/cm².
2. **Limited Approach Boundary:** Qualified or escorted unqualified persons only.
3. **Restricted Approach Boundary:** Qualified persons with PPE only.

Chapter 5

Industrial Hygiene: Noise

5.1 Hearing Conservation

5.1.1 Testing and Thresholds

- **Baseline Audiogram:** Must be conducted within 6 months of first exposure ≥ 85 dBA.
- **Standard Threshold Shift (STS):** An average shift of 10 dB or more at 2000, 3000, and 4000 Hz.

5.2 Decibel Math

5.2.1 Sound Pressure Level (SPL)

$$L_p = 20 \log \left(\frac{P}{P_0} \right)$$

Reference Pressure $P_0 = 20\mu Pa$.

5.2.2 Adding Decibels

To add two sound sources (L_1, L_2):

$$L_{total} = 10 \log \left(10^{L_1/10} + 10^{L_2/10} \right)$$

Rule of Thumb:

- Difference 0-1 dB: Add 3 dB to higher.
- Difference 2-3 dB: Add 2 dB.
- Difference 4-9 dB: Add 1 dB.
- Difference ≥ 10 dB: No change.

Chapter 6

Ventilation

6.1 System Components

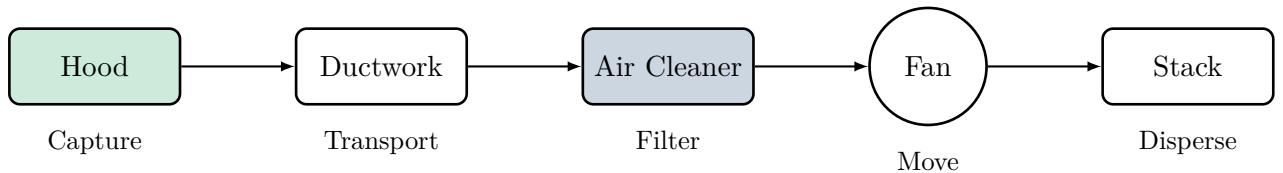


Figure 6.1: Standard LEV System Schematic

6.1.1 Hood Types

- **Canopy:** Used for hot processes where buoyant air rises.
- **Downdraft:** Used for contaminants heavier than air.
- **Enclosure:** Surrounds the process (e.g., Lab fume hood).
- **Receiving:** Captures emissions that have initial momentum (e.g., Grinding).

6.2 Ventilation Equations

$$Q = V \times A \quad (6.1)$$

Where Q is airflow (CFM), V is velocity (fpm), A is area (sq. ft).

6.3 Fan Laws

For a change in fan speed (N):

- CFM varies directly: $\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$
- SP varies as square: $\frac{SP_1}{SP_2} = \left(\frac{N_1}{N_2}\right)^2$
- HP varies as cube: $\frac{HP_1}{HP_2} = \left(\frac{N_1}{N_2}\right)^3$

Chapter 7

Radiation Safety

7.1 Ionizing Radiation Types

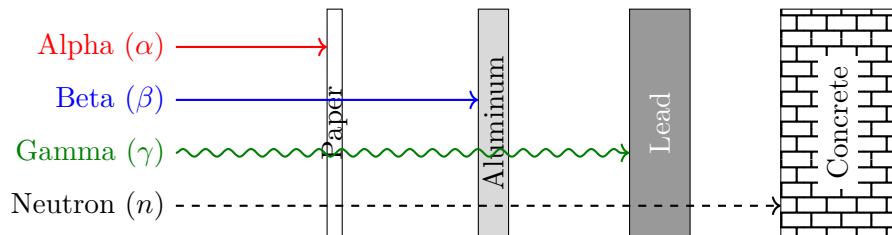


Figure 7.1: Radiation Penetration and Shielding

7.2 Protection Strategy (ALARA)

As Low As Reasonably Achievable.

1. **Time:** Minimize exposure duration.
2. **Distance:** Maximize distance (Inverse Square Law).

$$I_1 d_1^2 = I_2 d_2^2$$

3. **Shielding:** Use appropriate barriers.

Chapter 8

Thermal Stressors

8.1 Heat Stress

8.1.1 WBGT Index

Wet Bulb Globe Temperature assesses heat load.

- **Outdoor (with solar load):**

$$WBGT = 0.7WB + 0.2GT + 0.1DB$$

- **Indoor (no solar load):**

$$WBGT = 0.7WB + 0.3GT$$

8.2 Cold Stress

8.2.1 Wind Chill Factor

Estimates cooling power based on temperature (T in Fahrenheit) and wind speed (V in mph).

$$\text{Wind Chill} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16}) \quad (8.1)$$

Chapter 9

Engineering Economy and Statistics

9.1 Financial Formulas

9.1.1 Interest

- Simple Interest: $I = Pni$
- Compound Interest (Future Value):

$$F = P(1 + i)^n$$

- Present Value (PV):

$$P = \frac{F}{(1 + i)^n}$$

9.1.2 Return on Investment (ROI)

$$ROI = \frac{\text{Net Profit}}{\text{Cost of Investment}} \times 100$$

9.2 Statistics

- Mean (μ): Average of data points.
- Median: Middle value.
- Mode: Most frequently occurring value.
- Standard Deviation (σ): Measure of dispersion.

$$\sigma = \sqrt{\frac{\sum(x - \mu)^2}{N}}$$