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Lecture 2 – Sig Figs, Scientific Notation, units

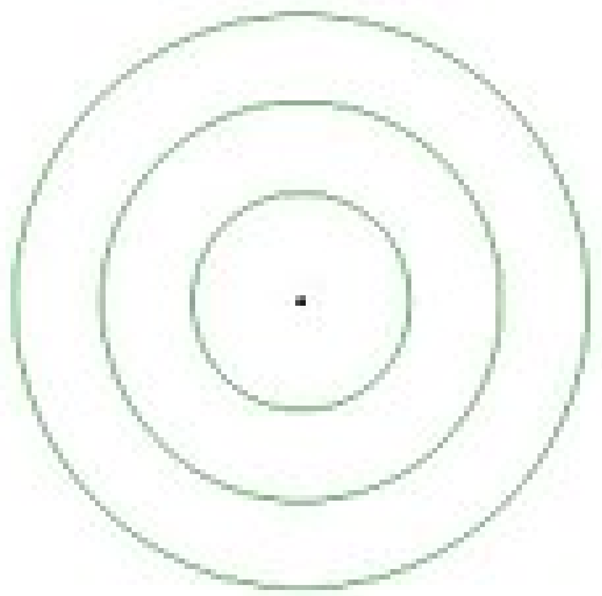
Accuracy, Precision and Bias

Physical meaning in measurements

- When you are thinking about accuracy and precision, think about throwing darts
- Accurate is true, precise is highly repeatable.

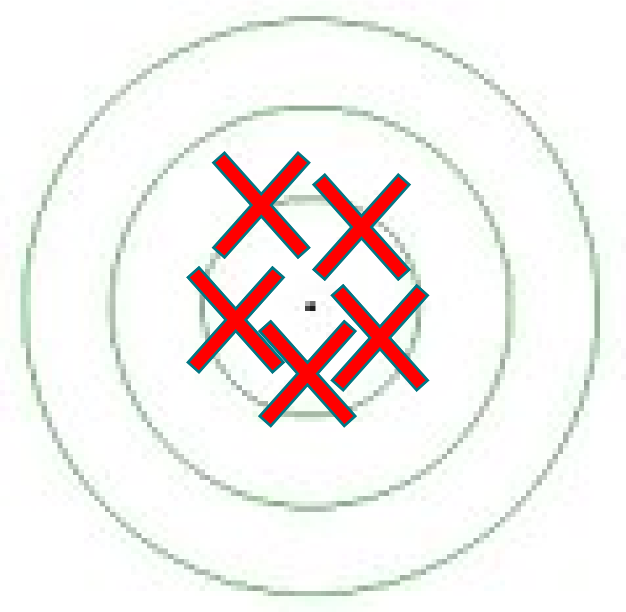
Accuracy, Precision and Bias

When you are accurate and precise



Accuracy, Precision and Bias

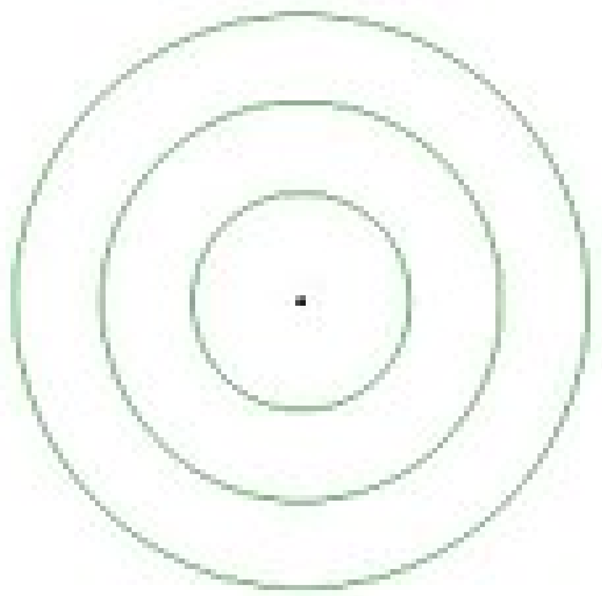
When you are accurate and precise



This is ideal!

Accuracy, Precision and Bias

When you are accurate, but you are not precise



Accuracy, Precision and Bias

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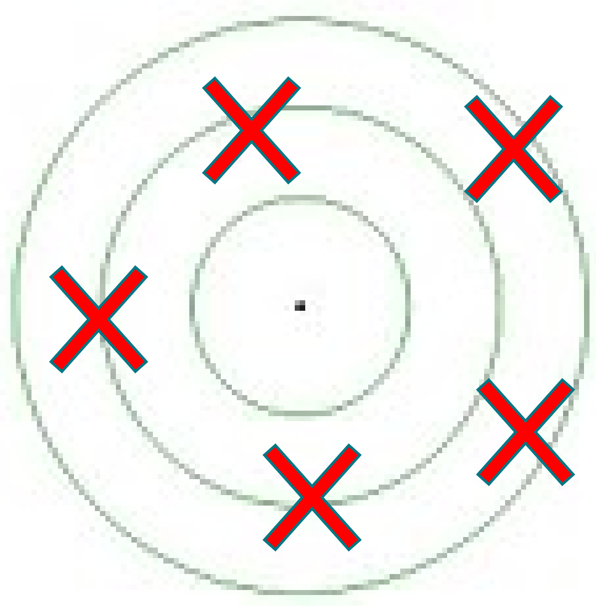


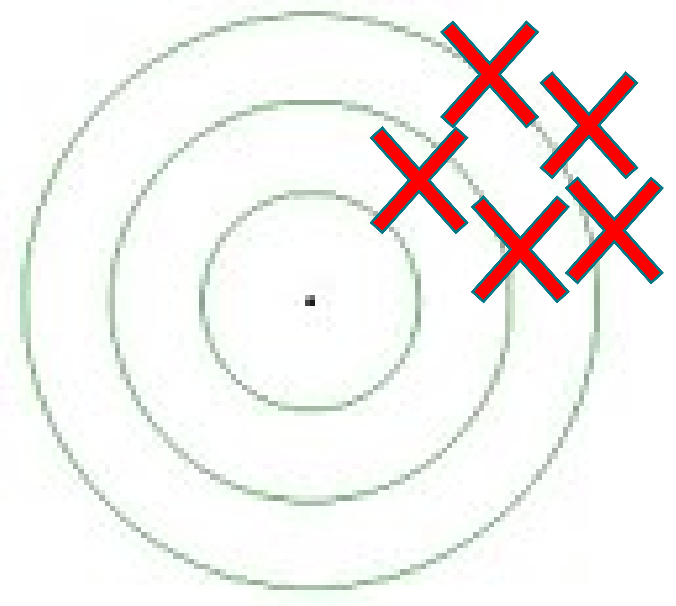
Accuracy, Precision and Bias

Bias is very common

- Bias is a systematic <u>shift</u> from accurate

Accuracy, Precision and Bias

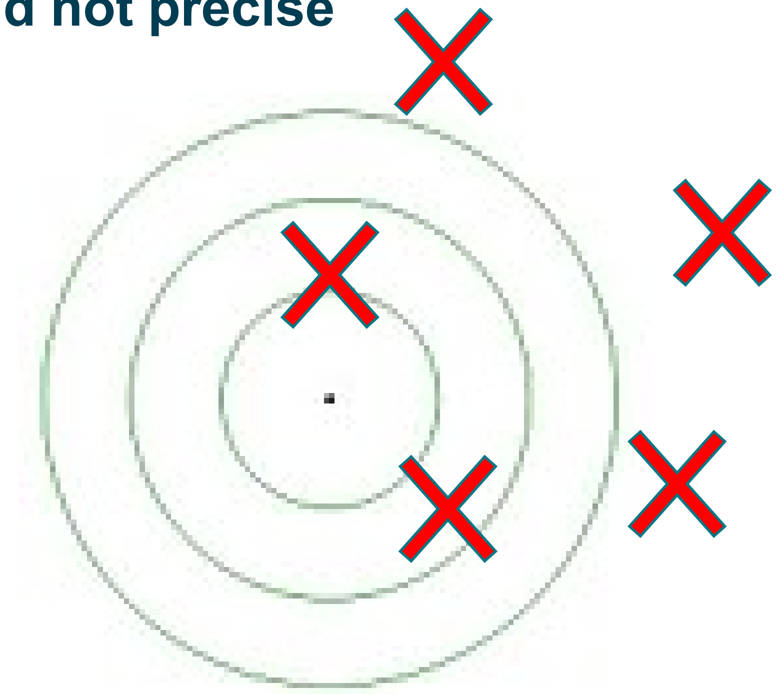
When you are precise but biased



This is a perfect time for calibration!

Accuracy, Precision and Bias

When you are biased and not precise



Sometimes this is the only realistic scenario

Significant Figures

Rule: The non zero digit is significant. The zeros before the decimal are not unless they are sandwiched by other non zero digits.

- 1000 has _______significant figures.
- 220 has _______ significant figures.
- 409 has _______ significant figures.

Significant Figures

Rule: The non zero digit is significant. The zeros before the decimal are not unless they are sandwiched by other non zero digits.

- 1000 has ____1___significant figures.
- 220 has ________ significant figures.
- 409 has ________ significant figures.

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Significant Figures

Rule: The non zero digit is significant. The zeros before the decimal are not unless they are sandwiched by other non zero digits.

- 1000 has ____1___significant figures.
- 220 has ____2___ significant figures.
- 409 has ________ significant figures.

Significant Figures

Rule: The non zero digit is significant. The zeros before the decimal are not unless they are sandwiched by other non zero digits.

- 1000 has ____1___significant figures.
- 220 has _____2___ significant figures.
- 409 has _____3___ significant figures.

Significant Figures

Rule: Zero values after the decimal place before the non zero digits are considered place holders and not significant.

- 0.046 has ___________significant figures.
- 0.00209 has ________ significant figures.
- 208.045 has ________ significant figures.

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Significant Figures

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- 0.046 has ________2_____significant figures.
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- 0.046 has ______2____significant figures.
- 0.00209 has ____3___ significant figures.
- 208.045 has ________ significant figures.

Significant Figures

Rule: Zero values after the decimal place before the non zero digits are considered place holders and not significant.

- 0.046 has ______2_____significant figures.
- 0.00209 has ____3___ significant figures.
- 208.045 has ____6___ significant figures.

Significant Figures

Rule: Trailing zero values to the right of a decimal number are inferring a degree of precision in measurements and are significant.

- 0.002100 has ___________significant figures.

Significant Figures

Rule: Trailing zero values to the right of a decimal number are inferring a degree of precision in measurements and are significant.

- 0.002100 has ______4______significant figures.

Significant Figures

- 809.0100 has ________7___significant figures.
- 240.0 has __________4___significant figures.
- 601.20 has _________5___significant figures.
- 4.8×10^4 has _________2___significant figures.

Significant Figures

Determining Significant Figures for Multiplication and Division

- How many significant figures for the answer to this equation?

$$130 \times 45 \times 101 \times 100.0$$

Significant Figures

Determining Significant Figures for Multiplication and Division

- For multiplication and division, the factor with the least number of significant figures determines the number of significant figures in the answer

Significant Figures

Determining Significant Figures for Multiplication and Division

- How many significant figures for the answer to this equation?

$$130 \times 45 \times 101 \times 100.0$$

  - 130 has _______2___significant figures.
  - 45 has ________2___significant figures.
  - 101 has _______3___significant figures.
  - 100.0 has _____4___significant figures.

Significant Figures

Determining Significant Figures for Multiplication and Division

- How many significant figures for the answer to this equation?

$$130 \times 45 \times 101 \times 100.0$$

- Answer with proper significant figures: 59000000
- Answer in scientific notation: $5.9 \text{x} 10^7$
- Answer in Engineering Notation: $59 \text{x} 10^6$

Significant Figures

Determining Significant Figures for unit definition

- How many significant figures for the following?
- 1 ft = 12 in
- Density of pure water = 1000 kg/m^3
- How precise are these measurement?

Significant Figures

Determining Significant Figures for unit definition

- How many significant figures for the following?
- 1 ft = 12 in
- Density of pure water = 1000 kg/m^3
- For unit definitions, assume infinite precision (and infinite significant figures)

Significant Figures

Determining Significant Figures for calculations

- Important strategies for calculations: leave rounding until the very end!
- Carry as many digits as possible through every step
- When reporting out the answer, determine the number of sig figs based on the values given in the problem (or the measured values)

Problem Solving Strategy

In this class we use DRPIE

- Define: Restate the problem concisely, stating assumptions
- Represent: Create a visual representation of the problem
- Plan: Create a plan for how to evaluate problem
- Implement: Work through your plan to arrive at a final answer
- Evaluate: Determine if the answer makes sense and state the answer concisely

Common units

Measurement	SI units	Other Common Engineering Units Used in this class
Length	m = meters	ft = feet in = inches cm = centimeters mm = millimeters miles
Energy= ______*_____	J = Joules	Kilowatt hrs
Power = _____	W = ________ W = J/s	MW = Megawatts KW = Kilowatts
Mass	kg =	g = grams
Weight & Force **(Weight is a _____)**	N =	lb
Time	s =	Days, hours, min, year etc.

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Common units

Measurement	SI units	Other Common Engineering Units Used in this class
Length	m = meters	ft = feet in = inches cm = centimeters mm = millimeters miles
Energy= Power * Time	J = Joules	Kilowatt hrs
Power = Energy / Time	W = Watts W = J/s	MW = Megawatts KW = Kilowatts
Mass	kg = kilograms	g = grams (lbm, pound mass)
Weight & Force (Weight is a Force)	N =Newtons	lb (lbf, pound force)
Time	s = seconds	Days, hours, min, year etc.

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Unit conversions

Sample problem 1: What is 43mm equivalent to in meters? (1000mm = 1 m)

Unit conversions

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Define: Convert 43mm to m.
Assume 1000mm = 1m

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Define: Convert 43mm to m.
Assume 1000mm = 1m

Represent:

$$\frac{43\text{ mm}}{\qquad\qquad} = \frac{\qquad\text{m}}{\qquad}$$

Unit conversions

Sample problem 1: What is 43mm equivalent to in meters? (1000mm = 1 m)

Define: Convert 43mm to m.
Assume 1000mm = 1m

Represent:

$$\frac{43\text{ mm}}{\quad} = \frac{\text{m}}{\quad}$$

Plan:

$$\frac{1\text{m}}{1000\text{mm}}$$

Unit conversions

Sample problem 1: What is 43mm equivalent to in meters? (1000mm = 1 m)

Define: Convert 43mm to m.
Assume 1000mm = 1m

Represent:

$$\frac{43\ \cancel{mm}}{} \Bigg| \frac{1\ m}{1000\ \cancel{mm}} = \frac{0.043m}{}$$

Plan:

$$\frac{1m}{1000mm}$$

$\boxed{\text{43mm is equivalent to 0.043m}}$

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Unit conversions

Sample problem 2: What is $2.4 m^2$ equivalent to in ft^2? (3.281 ft = 1.000 m)

Unit conversions

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Define: Convert $2.4m^2$ to ft^2

Assume 3.281 ft = 1.000 m

Unit conversions

Sample problem 2: What is 2.4m^2 equivalent to in ft^2? (3.281 ft = 1.000 m)

Define: Convert 2.4m^2 to ft^2

Assume 3.281 ft = 1.000 m

Represent:

$$\frac{2.4\ m^2}{\quad} \Bigg| \frac{\qquad\qquad}{\qquad\qquad} = \frac{\quad ft^2}{\quad}$$

Unit conversions

Sample problem 2: What is $2.4 m^2$ equivalent to in ft^2? (3.281 ft = 1.000 m)

Define: Convert $2.4 m^2$ to ft^2

Assume 3.281 ft = 1.000 m

Represent:

$$\begin{array}{l|l} 2.4\ m^2 & \\ \hline & \end{array} = \frac{ft^2}{}$$

Plan:

$$\frac{3.281\ ft}{1.000 m}$$

Unit conversions

Sample problem 2: What is $2.4 m^2$ equivalent to in ft^2? (3.281 ft = 1.000 m)

Define: Convert $2.4 m^2$ to ft^2

Assume 3.281 ft = 1.000 m

Represent:

$$\begin{array}{l|l|l} 2.4\ m^2 & 3.281\ ft & 3.281\ ft \\ \hline & 1.000\ m & 1.000\ m \end{array} = \frac{ft^2}{}$$

Plan:

$$\frac{3.281\ ft}{1.000 m}$$

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Unit conversions

Sample problem 2: What is 2.4m^2 equivalent to in ft^2? (3.281 ft = 1.000 m)

Define: Convert 2.4m^2 to ft^2

Assume 3.281 ft = 1.000 m

Represent:

$$\frac{2.4\ \cancel{m^2}}{} \cdot \frac{3.281\ ft}{1.000\ \cancel{m}} \cdot \frac{3.281\ ft}{1.000\ \cancel{m}} = \frac{26\ ft^2}{}$$

Plan:

$$\frac{3.281\ ft}{1.000m}$$

$\boxed{\text{2.4m}^2 \text{ is equivalent to 26ft}^2}$

Unit conversions

Sample problem 3a: If 24 m^3 of water flows through a pipe in one hour, what is the flow in ft^3/s ? (3.281 ft = 1.000 m)

Unit conversions

Sample problem 3a: If 24 m^3 of water flows through a pipe in one hour, what is the flow in ft^3/s ? (3.281 ft = 1.000 m)

Define: Convert $24 m^3/hr$ to ft^3/s

Assume 3.281 ft = 1.000 m , 1 hour = 60 minutes , 1 minute = 60 seconds

Unit conversions

Sample problem 3a: If 24 m^3 of water flows through a pipe in one hour, what is the flow in ft^3/s ? (3.281 ft = 1.000 m)

Define: Convert 24m^3/hr to ft^3/s

Assume 3.281 ft = 1.000 m , 1 hour = 60 minutes , 1 minute = 60 seconds

Represent:

$$\frac{24\ \text{m}^3}{1\ \text{hour}} \Bigg| \qquad\qquad = \frac{\text{ft}^3}{\text{second}}$$

Unit conversions

Sample problem 3a: If 24 m^3 of water flows through a pipe in one hour, what is the flow in ft^3/s ? (3.281 ft = 1.000 m)

Define: Convert 24m^3/hr to ft^3/s

Assume 3.281 ft = 1.000 m , 1 hour = 60 minutes , 1 minute = 60 seconds

Represent:

$$\frac{24\ m^3}{1\ hour} \Bigg| \qquad = \frac{ft^3}{second}$$

Plan:

$$\frac{3.281\ ft}{1.000m} \qquad \frac{1\ hour}{60\ minutes} \qquad \frac{1\ minute}{60\ seconds}$$

Unit conversions

Sample problem 3a: If 24 m^3 of water flows through a pipe in one hour, what is the flow in ft^3/s ? (3.281 ft = 1.000 m)

Define: Convert 24m^3/hr to ft^3/s

Assume 3.281 ft = 1.000 m , 1 hour = 60 minutes , 1 minute = 60 seconds

Represent:

$$\frac{24\ m^3}{1\ hour} \times \frac{3.281\ ft}{1.000\ \cancel{m}} \times \frac{3.281\ ft}{1.000\ \cancel{m}} \times \frac{3.281\ ft}{1.000\ \cancel{m}} \times \frac{1\ \cancel{hour}}{60\ \cancel{min}} \times \frac{1\ \cancel{min}}{60\ second} = \frac{0.24\ ft^3}{second}$$

Plan:

$$\frac{3.281\ ft}{1.000m} \quad \frac{1\ hour}{60\ minutes} \quad \frac{1\ minute}{60\ seconds}$$

24 m^3/hour is equivalent to 0.24 ft^3/second

Unit conversions

Sample problem 3b: If 24 m^3 of water flows through a pipe in one hour, what is the flow in kg/s ? (Density of water is 1000kg/m^3)

Unit conversions

Sample problem 3b: If 24 m^3 of water flows through a pipe in one hour, what is the flow in kg/s ? (Density of water is 1000kg/m^3)

Define: Convert 24m^3/hr to kg/s

Assume 1000 kg= 1.000 m^3 , 1 hour = 60 minutes , 1 minute = 60 seconds

Represent:

$$\frac{24\ \cancel{m^3}}{1\ \text{hour}} \left| \frac{1000\ \text{kg}}{1.000\ \cancel{m^3}} \right| \frac{1\ \cancel{\text{hour}}}{60\ \cancel{\text{min}}} \left| \frac{1\ \cancel{\text{min}}}{60\ \text{second}} \right. = \frac{6.7\ \text{kg}}{\text{second}}$$

Plan:

$$\frac{1000\ \text{kg}}{1.000\text{m}^3} \quad \frac{1\ \text{hour}}{60\ \text{minutes}} \quad \frac{1\ \text{minute}}{60\ \text{seconds}}$$

24 m^3/hour is equivalent to 6.7 kg/second

Unit conversions

Sample problem 3c: If 24 m^3 of water flows through a pipe in one hour, what is the flow in gallons/min ? (1.000 gallons = 0.003786 m^3)

Unit conversions

Sample problem 3c: If 24 m^3 of water flows through a pipe in one hour, what is the flow in gallons/min ? (1.000 gallons = 0.003786 m^3)

Define: Convert 24m^3/hr to gallon/minute

Assume 1.000 gallon= 0.003786 m^3 , 1 hour = 60 minutes

Represent:

$$\frac{24\ m^3}{1\ hour}\left|\frac{1.000\ gallon}{0.003786\ \cancel{m^3}}\right|\frac{1\ \cancel{hour}}{60\ min} = \frac{110\quad gallon}{minute}$$

Plan:

$$\frac{1.000\ gallon}{0.003786\ m^3} \qquad \frac{1\ hour}{60\ minutes}$$

$\boxed{\text{24 m}^3\text{/hour is equivalent to 110 gallon/minute}}$

Unit analysis

Sample problem 4: You are given the formula: Resistance = R = ρL/A

If R is in ohms, ρ (resistivity) is in ohm.m , L (Length) is in m then what must be the units for the area (A) ?

Unit analysis

Sample problem 4: You are given the formula: Resistance = R = ρL/A
If R is in ohms, ρ (resistivity) is in Ωm , L (Length) is in m then what must be the units for the area (A) ?

Define: Find the units of A in the equation R = ρ*L/A
Assume R has units ohms, rho has units ohm meters, and L has units of meters

Unit analysis

Sample problem 4: You are given the formula: Resistance = R = ρL/A
If R is in ohms, ρ (resistivity) is in ohm.m , L (Length) is in m then what must be the units for the area (A) ?

Define: Find the units of A in the equation R = rho*L/A
Assume R has units ohms, rho has units ohm meters, and L has units of meters

Represent:

$$R = \frac{\rho L}{A}$$

Unit analysis

Sample problem 4: You are given the formula: Resistance = R = ρL/A
If R is in ohms, ρ (resistivity) is in ohm.m , L (Length) is in m then what must be the units for the area (A) ?

Define: Find the units of A in the equation R = rho*L/A
Assume R has units ohms, rho has units ohm meters, and L has units of meters

Represent:

$$R = \frac{\rho L}{A}$$

Plan: Rearrange the equation so that A is on its own, replace variables with units, cross out like terms

Unit analysis

Sample problem 4: You are given the formula: Resistance = R = ρL/A
If R is in ohms, ρ (resistivity) is in ohm.m , L (Length) is in m then what must be the units for the area (A) ?

Define: Find the units of A in the equation R = rho*L/A
Assume R has units ohms, rho has units ohm meters, and L has units of meters

Represent:

$$R = \frac{\rho L}{A} \qquad A = \frac{\rho L}{R} \qquad A = \frac{\Omega m \times m}{\Omega} \qquad A = \frac{\cancel{\Omega} m^2}{\cancel{\Omega}} \qquad \boxed{A = m^2}$$

Plan: Rearrange the equation so that A is on its own, replace variables with units, cross out like terms

$\boxed{\text{The units of A are } m^2}$

Unit analysis

Rules about units:

- Units act just like variables in algebra
- You can’t add or subtract unlike units
- You can multiply and divide unlike units
- You can cancel out units

Common units

Power	Prefix	Abbreviation
10^{-9}	nano	n
10^{-6}	micro	µ
10^{-3}	milli	m
10^{-2}	centi	c
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G

Unit conversions

Sample problem 5: Covert 122mm to m

Unit conversions

Sample problem 5: Covert 122mm to m

Define: Convert 122 millimeters to meters

Assume 1m = 1000 mm

Represent:

$$\frac{122\ \text{mm}}{} \left| \frac{1\text{m}}{1000\ \text{mm}} \right. = \frac{0.122\ \text{m}}{}$$

Plan:

$$\frac{1\ \text{m}}{1000\ \text{mm}}$$

122 mm is equivalent to 0.122 m

Unit conversions

Sample problem 6: Covert $36m^2$ to mm^2

Unit conversions

Sample problem 6: Covert $36m^2$ to mm^2

Define: Convert 36 square meters to square millimeters
Assume 1m = 1000 mm

Represent:

$$\frac{36\ m^2}{} \left| \frac{1000\ mm}{1m} \right| \frac{1000\ mm}{1m} = \frac{3.6\text{x}10^7\ mm^2}{}$$

Plan:

$$\frac{1\ m}{1000\ mm}$$

$\boxed{36\ m^2 \text{ is equivalent to } 3.6\text{x}10^7\ mm^2}$

Unit conversions

Sample problem 7: Covert 23MW to W

Unit conversions

Sample problem 7: Covert 23MW to W

Define: Convert 23 Megawatts to Watts
Assume 1MW = 1000000W

Represent:

$$\frac{23\ \text{MW}}{} \left| \frac{1000000\ \text{W}}{1\ \text{MW}} \right. = \frac{23000000\ \text{W}}{}$$

Plan:

$$\frac{1\ \text{MW}}{1000000\ \text{W}}$$

23 MW is equivalent to 2.3×10^7 W

Percent Error

When to use Percent Error:

- Comparing your results to what <u>your results</u> should have been <u>in theory</u>
- Theoretical results are often calculated from a calculated source or measurements using high accuracy/precision measurements and closely controlled conditions

$$Percent\ error = \frac{X_{measured} - X_{theoretical}}{X_{theoretical}} \times 100$$

Percent Error

Sample problem 8: Your experiment found the Young's Elastic Modulus of 304 Stainless steel to be 189 GPa. The accepted value for this material is 193 GPa. What is the % error of your experiment?

Define: Calculate the percent difference

$X_{measured}$ = 189 Gpa , $X_{theoretical}$ = 193 GPa

Represent:

$$Percent\ error = \frac{X_{measured} - X_{theoretical}}{X_{theoretical}} \times 100 \quad Percent\ error = \frac{189 - 193}{193} \times 100$$

Plan:

Substitute $X_{measured}$ and $X_{theoretical}$

The percent difference is -2.07%

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Percent Difference

When to use Percent Difference:

- Comparing two different measurement methods or two different experimental values

$$Percent\ difference = \frac{|X_1 - X_2|}{{}^{1}/{}_{2}\,(X_1 + X_2)} \times 100$$

Percent Difference

Sample problem 9: Team A had the value of the Young's Elastic modulus as 189 GPa but Team B had the value of 195 GPa. What is the % difference?

Define: Calculate the percent difference

X_1 = 189 Gpa , X_2 = 195 GPa

Represent:

$$Percent\ difference = \frac{|X_1 - X_2|}{{}^{1}/_{2}\,(X_1 + X_2)} \times 100$$

$$Percent\ difference = \frac{|189 - 195|}{{}^{1}/_{2}\,(189 + 195)} \times 100$$

Plan:

Substitute X_1 and X_2

The percent difference is 3.13%

Thank you!

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