INTRODUCTION

Learning Objectives

1). To introduce and define the subject of *mechanics*.

2). To introduce *Newton's Laws*, and to understand the significance of these laws.

3). The review *modeling, dimensional consistency*, *unit conversions* and *numerical accuracy* issues.

4). To review basic *vector algebra* (i.e., vector addition and subtraction and scalar multiplication).

Definitions

Mechanics: Study of forces acting on a rigid body

a) *Statics* - body remains at rest

b) *Dynamics* - body moves

Newton's Laws

First Law: Given *no net force*, a body at rest will remain at rest and a body moving at a constant velocity will continue to do so along a straight path $\left(\sum \bar{F}=0, \sum \bar{M}=0\right)$.

Second Law: Given a *net force* is applied, a body will experience an acceleration in the direction of the force which is proportional to the net applied force $\sum \bar{F}=m\bar{a}$.

Third Law: For each action there is an *equal and opposite* reaction $\bar{F}_{AB}=-\bar{F}_{BA}$.

Models of Physical Systems

Develop a model that is representative of a physical system

Particle: a body of infinitely small dimensions (conceptually, a point).

Rigid Body: a body occupying more than one point in space in which all the points remain a fixed distance apart.

Deformable Body: a body occupying more that one point in space in which the points do not remain a fixed distance apart.

Dimensional Consistency

If you add together two quantities,

$$x = C_1\ v + C_2 a$$

these quantities need to have the same dimensions (units); e.g., if x, v and a have units of (L), (L/T) and (L/T^2), then C_1 and C_2 must have units of (T) and T^2 to maintain dimensional consistency.

Many times algebraic errors in analysis lead to dimensional inconsistency. *Use dimensional consistency as a check on your algebra.*

Unit Conversions

Use a logical process in your unit conversions. For example, to convert 60 mph to ft/sec:

$$60\frac{\text{miles}}{\text{hour}} \times \frac{\text{hour}}{3600\,\text{s}} \times \frac{5280\text{ft}}{\text{mile}} = 88\frac{\text{ft}}{\text{s}}$$

Accuracy of Numerical Answers

Say that you do the following calculations:

$$z = \frac{x}{y} + t$$

Say that you have used four significant digits for x and y but only two significant digits for t. The numerical value of z will not have more than two significant digits (and likely less than two).

Examples of Significant Figures:

385.1	four significant figures
38.51	four significant figures
0.03851	four significant figures
3.851×10^{7}	four significant figures
7.04×10^{-4}	three significant figures
25.5	three significant figures
0.51	two significant figures
0.00005	one significant figure
27.855	five significant figures
8.91×10^{4}	three significant figures
2200	May have two, three or four significant figures depending on the accuracy of the measurement that obtained the number. Where such doubt may exist, it is better to write the number as 2.2×10^{3} to show two significant figures; or as 2.20×10^{3} to show three significant figures.
55	two significant figures

55.0 three significant figures. The zero is significant in this case, since it is not otherwise needed to show proper location of the decimal point.

Retention of Significant Figures

1. In recording measured data, only one doubtful digit is retained, and it is considered to be a significant figure.
2. In dropping figures that are not significant, the last figure retained should be increased by 1 if the first figure dropped is 5 or greater.
3. In addition and subtraction, do not carry the result beyond the first column that contains a doubtful figure. For example,

$$\begin{array}{r} 11.3 \\ +\ 31.43 \\ \hline 42.73 \end{array} = 42.7$$

(the 3 in the hundredth's place is insignificant since the 11.3 figure can only be measured to the closest tenth).

4. In multiplication and division, carry the result to the same number of significant figures that there are in the quantity entering into the calculation that has the least number of significant figures. For example,

$$\begin{array}{r} 15.5 \\ \times\ 5.4 \end{array}$$

Note: Unless stated otherwise, we shall retain three significant figures (unless one or more digits are lost through additions; for example, 90.2 - 90.1 = 0.1). Thus, given a dimension of 2 ft, assume it is actually 2.00 ft.

Vectors

Vectors are characterized by both a magnitude and direction. Examples of vectors: position, velocity, acceleration, force, moment.

Vectors add by the parallelogram law. For example.

$$\overline{A} = \overline{B} + \overline{C}$$

Says that vector $\overline{A}$ has the same magnitude and direction as the sum of vectors $\overline{B}$ and $\overline{C}$.

More the tail of $\overline{C}$ to the head of $\overline{B}$. $\overline{A}$ is then found by connecting tail of $\overline{B}$ to the head of $\overline{C}$.

See the text for the mechanics of adding and subtracting vectors and for multiplying a scalar with a vector.

Law of Cosines:

$$C=\sqrt{A^2 + B^2 - 2AB \cos c}$$

Law of Sines:

$$\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c}$$

History of Mechanics

Three divisions: Mechanics of Rigid Bodies
Mechanics of Deformable Bodies
Mechanics of Fluids

Aristotle (384-322 BC) – first to investigate the statics of levers and the first to develop some of the first theories of dynamics

Archimedes (287-212 BC) – explained the lever fulcrum and the theory of buoyancy

da Vinci (1452-1519) – continued Archimedes work on levers and developed a theory on moments for 3-D bodies

Brahe (1546-1601) – developed accurate astronomical measurements

Kepler (1571-1630) – developed laws of planetary motion

Stevinus (1548-1620) – conceived the laws of equilibrium and the parallelogram law for vector addition

Galileo (1564-1642) – studied projectile motion and took strong stance against natural philosophers and the Catholic Church

Descartes (1596-1650) – developed Cartesian coordinate system and the theory of virtual work

Hooke (1635-1703) – Developed theory of elasticity (Hooke's Law)

Newton (1642-1727) – Invented calculus (with Gottfried Leibniz) and wrote the Mathematical Principles of Natural Philosophy, the foundation for Newton's Laws of Motion and classical mechanics

Newton laid the foundation for future contributors like Euler, Lagrange, Cauchy, Kolmogorov, and many others.