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دانشکده مهندسی مکانیک

درس دینامیک

Engineering Mechanics Dynamics

Meriam, Kraige & Bolton

9th Edition

Chapter 1: **Introduction to Dynamics**

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PART I

Dynamics of Particles

CHAPTER 1

Introduction to Dynamics

CHAPTER OUTLINE

NASA

The International Space Station's Canadarm2 grapples the Kounotori2 H-II Transfer Vehicle as it approaches the station in 2011.

1/1 History and Modern Applications

History of Dynamics

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Galileo Galilei

Portrait of Galileo Galilei (1564–1642) (oil on canvas), Sustermans, Justus (1597–1681) (school of)/ Galleria Palatina, Florence, Italy/Bridgeman Art Library.

Applications of Dynamics

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Artificial hand

1/2 Basic Concepts

- **Space** is the geometric region occupied by bodies.
  - The basic frame of reference for the laws of Newtonian mechanics is the primary inertial system or astronomical frame of reference, which is an imaginary set of rectangular axes assumed to have no translation or rotation in space.

- ***Time*** is a measure of the succession of events and is considered an absolute quantity in Newtonian mechanics.

- ***Mass*** is the quantitative measure of the inertia or resistance to change in motion of a body.

1/2 Basic Concepts

- ***Force*** is the vector action of one body on another.

- A ***Particle*** is a body of negligible dimensions.

- A ***Rigid Body*** is a body whose changes in shape are negligible compared with the overall dimensions of the body or with the changes in position of the body as a whole.

- ***Vector*** and ***Scalar*** quantities

1/3 Newton's Laws

- ***Law I.*** A particle remains at rest or continues to move with uniform velocity (in a straight line with a constant speed) if there is no unbalanced force acting on it.

- ***Law II.*** The acceleration of a particle is proportional to the resultant force acting on it and is in the direction of this force.

$$\mathbf{F} = m\mathbf{a}$$

- ***Law III.*** The forces of action and reaction between interacting bodies are equal in magnitude, opposite in direction, and collinear.

1/4 Units

- International System of metric units (SI)
- U.S. Customary system of units

Quantity	Dimensional Symbol	SI Units: Unit	SI Units: Symbol	U.S. Customary Units: Unit	U.S. Customary Units: Symbol
Mass	M	kilogram (base unit)	kg	slug	—
Length	L	meter* (base unit)	m	foot (base unit)	ft
Time	T	second (base unit)	s	second (base unit)	sec
Force	F	newton	N	pound (base unit)	lb

*Also spelled *metre*.

Omikron/Photo Researchers, Inc.

The U.S. standard kilogram at the National Bureau of Standards.

SI Units	U.S. Customary Units
$(1 \text{ N}) = (1 \text{ kg})(1 \text{ m/s}^2)$	$(1 \text{ lb}) = (1 \text{ slug})(1 \text{ ft/sec}^2)$
$\text{N} = \text{kg} \cdot \text{m/s}^2$	$\text{slug} = \text{lb} \cdot \text{sec}^2/\text{ft}$

1/5 Gravitation

- Newton's law of gravitation, which governs the mutual attraction between bodies

$$F = G\frac{m_1 m_2}{r^2}$$

F = the mutual force of attraction between two particles

G = a universal constant called the *constant of gravitation*

m_1, m_2 = the masses of the two particles

r = the distance between the centers of the particles

$$G = 6.673(10^{-11})\ \text{m}^3/(\text{kg}\cdot\text{s}^2)$$

1/5 Gravitation

Effect of Altitude

$$g = \frac{Gm_e}{R^2} \longrightarrow g = g_0 \frac{R^2}{(R+h)^2}$$

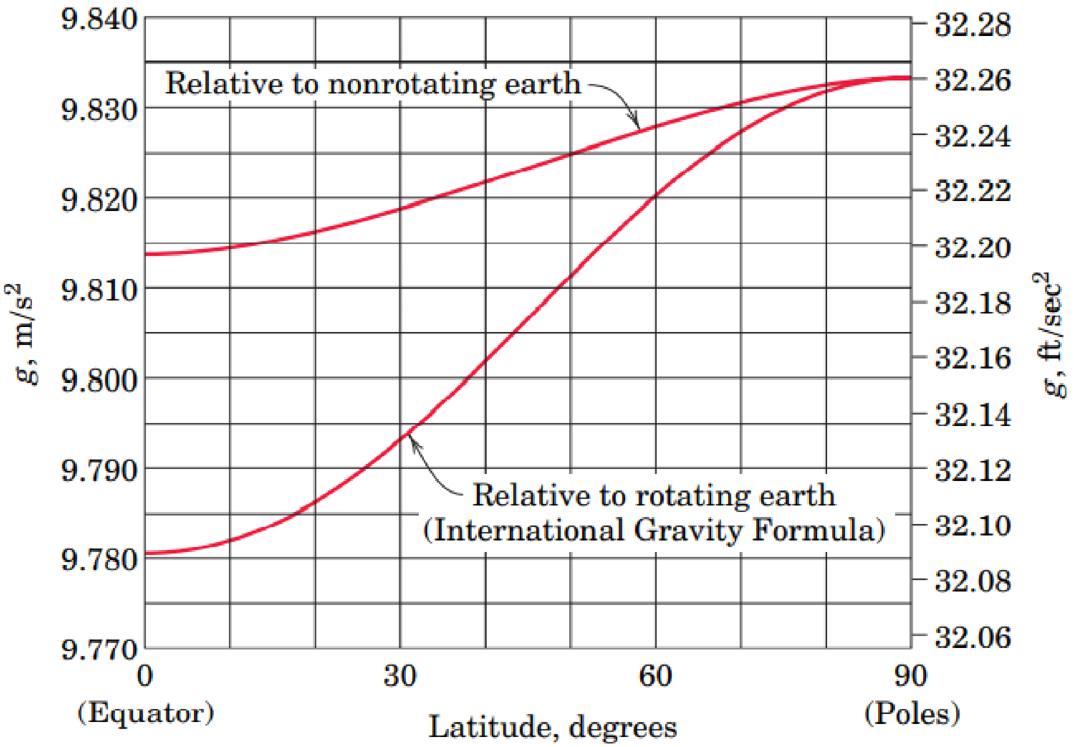
$$g = 9.825 \text{ m/s}^2$$

1/5 Gravitation

Effect of a Rotating Earth

$$g = 9.780\,327(1 + 0.005\,279 \sin^2 \gamma + 0.000\,023 \sin^4 \gamma + \cdots)$$

γ is the latitude



1/5 Gravitation

Standard Value of *g*

the rotating earth at sea level and at a latitude of 45°

→ $9.806\,65\ \text{m/s}^2$ or $32.1740\ \text{ft/sec}^2$

$9.81\ \text{m/s}^2$ in SI units

$32.2\ \text{ft/sec}^2$ in U.S. customary units

Apparent Weight

$$\mathbf{W} = m\mathbf{g}$$

1/6 Dimensions

- A given dimension such as length can be expressed in a number of different units such as meters, millimeters, or kilometers.

- Thus, a *dimension* is different from a *unit*.

- The *principle of dimensional homogeneity* states that all physical relations must be dimensionally homogeneous

$$F = ML/T^2$$

1/7 Solving Problems in Dynamics

Approximation in Mathematical Models

- Construction of an idealized mathematical model for a given engineering problem always requires approximations to be made. Some of these approximations may be mathematical, whereas others will be physical.

Application of Basic Principles

- The subject of dynamics is based on a surprisingly few fundamental concepts and principles which, however, can be extended and applied over a wide range of conditions.
- The definition of the system to be analyzed is made clear by constructing its **free-body diagram (FBD)** .

Numerical versus Symbolic Solutions

1/7 Solving Problems in Dynamics

- 1. Formulate the problem:
  - (a) State the given data.
  - (b) State the desired result.
  - (c) State your assumptions and approximations.
- 2. Develop the solution:
  - (a) Draw any needed diagrams, and include coordinates which are appropriate for the problem at hand.
  - (b) State the governing principles to be applied to your solution.
  - (c) Make your calculations.
  - (d) Ensure that your calculations are consistent with the accuracy justified by the data.
  - (e) Be sure that you have used consistent units throughout your calculations.
  - (f) Ensure that your answers are reasonable in terms of magnitudes, directions, common sense, etc.
  - (g) Draw conclusions.