Force Lesson Plan: Background

"Engineering Mechanics: Statics and Dynamics" , R.C. Hibbeler, 8th edition

(p.4-8)

A force is completely characterized by its magnitude, direction, and point of application.

Newton's Three Laws of Motion:

The entire subject of a rigid-body mechanics is formulated on the basis of Newton's three laws of motion, the validity of which is based on experimental observation. They apply to the motion of a particle as measured from a nonaccelerating reference frame.

First Law: A particle originally at rest, or moving in a straight line with constant velocity, will remain in this state provided the particle is NOT subjected to an unbalanced force

Second Law: A particle acted upon by an unbalanced force F experiences an acceleration **a** that has the same direction as the force and magnitude that is directly proportional to the force. If the force F is applied to a particle of mass m, this law may be expressed mathematically as:

$$F = ma$$

Third Law: the mutual forces of action and reaction between two particles are equal, opposite, and collinear (every action has equal and opposite reaction)

Newton's Law of Gravitation Attraction:

Newton postulated a law governing the gravitational attraction between any two particles:

$$F = G * \frac{m1 * m2}{r^2} \qquad (1)$$

F: the force of gravitation between the two particles
G: universal constant of gravitation; according to experimental evidence,
G = 66.73(10-12) $m^3/(kg*s^2)$
m1,m2: mass of each of the two particles
r: distance between the two particles

Weight:

According to equation 1 above, any two particles or bodies have a mutual attractive (gravitational) force acting between them. In the case of a particle located at or near the surface of the Earth, however, the only gravitational force having any sizable magnitude is that between the earth and the particle. Consequently, this force is termed the **weight**. From equation 1 above, an approximate expression for finding the weight W of a particle having a mass m1 = m, and if we assume the Earth to be a nonrotating sphere of constant density and having a mass m2= Me, then if r is the distance between the earth's center and the particle, we have

$$W = G * \frac{m * Me}{r^2}$$

letting $g = GMe / r^2$

we obtain: $W = mg$ (2)

We term g the acceleration due to gravity. Since it depends on r, it can be seen that the weight of a body is not an absolute. Instead, its magnitude is determined from where the measurement was made.

SI Units: The International System of units is a modern version of the metric system. SI system specifies length in meters, time in seconds, and mass in kilograms. The unit of force, called a Newton, is **derived** from F=ma. 1 Newton is equal to a force required to give 1 kilogram of mass an acceleration of $1 m/s^2$ ($N = \frac{kg * m}{s^2}$)

If the weight of a body located at the "standard location" is to be determined in Newtons, then equation 2 must be applied. In equation 2, $g = 9.81\ m/s^2$.

U.S. Customary: U.S. Customary system of units (FPS) length is measured in feet, force in pounds, and time in seconds. Unit of mass is called the slug, derived from F=ma. 1 slug is equal to the amount of matter accelerated at $1 ft/s^2$.

Conversion Units:

1 ft = 12 in
5280 ft = 1 mi
1000 lbs = 1 kip (kilopound)
2000 lbs = 1 ton

Quantity	**Unit of Measurement (FPS)**	**Unit of Measurement (SI)**
Force	lbs	4.4482 N
Mass	slug	14.5938 kg
Length	ft	0.3048 m