

INTRODUCTION TO STATICS:

1-1 Mechanics:

Mechanic's is the oldest of the physical sciences which deals with the effects of forces on objects.

The subject of mechanics is logically divided into two parts

1. Statics: statics is part of mechanics which concerns the equilibrium of bodies under the action of forces.
2. Dynamics: dynamics is a part of mechanics which concerns the motion of bodies.

1-2 SCALARS AND VECTORS:

We use two kinds of quantities in mechanics— scalars and vectors.

Scalar quantities are those with which only a magnitude is associated. Examples of scalar quantities are time, volume, density, speed, energy, and mass.

Vector quantities, on the other hand possess direction as well as magnitude, and must obey the parallelogram law. Examples of vector quantities are displacement, velocity, acceleration, force, moment, and momentum.

1-3 NEWTON'S LAWS OF MOTION:

First Law: (Inertia)

- An object at rest remains at rest unless acted upon by a force.
- An object in motion continues moving in a straight line at a constant velocity until acted upon by a force

Second Law:

- Acceleration of an object is directly proportional to the net force acting on the object and inversely proportional to its mass or:

$$\mathbf{F = ma} \quad \text{-----} \quad \text{Eq 1}$$

Where: F = force, m = mass, a = acceleration

ENGINEERING MECHANICS STATIC

Third Law:

- Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first or:

For every action, there is an equal and opposite reaction

1-4 UNITS:

In mechanics we use four fundamental quantities called dimensions. These are length, mass, force, and time. The four fundamental dimensions and their units and symbols in the most commonly systems are summarized in the following table.

QUANTITY	DIMENSIONAL SYMBOL	SI UNITS		U.S. CUSTOMARY UNITS		
		UNIT	SYMBOL	UNIT	SYMBOL	
Mass	M	Base units	kilogram	kg	slug	—
Length	L		meter	m	foot	ft
Time	T		second	s	second	sec
Force	F		newton	N	pound	lb

From equation 1

$$\begin{array}{ccc}
 \mathbf{F} & = & \mathbf{m} \quad \mathbf{a} \\
 \downarrow & & \downarrow \quad \downarrow \\
 \mathbf{N} & & \mathbf{kg} \quad \mathbf{m/s^2}
 \end{array}$$



$$\mathbf{N} = \mathbf{kg \cdot m/s^2} \quad \Longrightarrow \quad \mathbf{SI \ units}$$

Thus (1 Newton) is the force required to give a mass of (1 kg) an acceleration of (1 m/s²).

$$\begin{array}{ccc}
 \mathbf{F} & = & \mathbf{m} \quad \mathbf{a} \\
 \downarrow & & \downarrow \quad \downarrow \\
 \mathbf{lb} & & \mathbf{slug} \quad \mathbf{ft/sec^2}
 \end{array}$$



$$\mathbf{lb} = \mathbf{slug \cdot ft/sec^2} \quad \Longrightarrow \quad \mathbf{U.S. \ customary \ units}$$

Thus (1 lb) is the force required to give a mass of (1 slug) an acceleration of (1 ft/sec²).

ENGINEERING MECHANICS STATIC

Conversion Factors U.S. Customary Units to SI Units

To convert from	To	Multiply by
<i>(Acceleration)</i>		
foot/second ² (ft/sec ²)	meter/second ² (m/s ²)	$3.048 \times 10^{-1*}$
inch/second ² (in./sec ²)	meter/second ² (m/s ²)	$2.54 \times 10^{-2*}$
<i>(Area)</i>		
foot ² (ft ²)	meter ² (m ²)	9.2903×10^{-2}
inch ² (in. ²)	meter ² (m ²)	$6.4516 \times 10^{-4*}$
<i>(Density)</i>		
pound mass/inch ³ (lbm/in. ³)	kilogram/meter ³ (kg/m ³)	2.7680×10^4
pound mass/foot ³ (lbm/ft ³)	kilogram/meter ³ (kg/m ³)	1.6018×10
<i>(Force)</i>		
kip (1000 lb)	newton (N)	4.4482×10^3
pound force (lb)	newton (N)	4.4482
<i>(Length)</i>		
foot (ft)	meter (m)	$3.048 \times 10^{-1*}$
inch (in.)	meter (m)	$2.54 \times 10^{-2*}$
mile (mi), (U.S. statute)	meter (m)	1.6093×10^3
mile (mi), (international nautical)	meter (m)	$1.852 \times 10^3*$
<i>(Mass)</i>		
pound mass (lbm)	kilogram (kg)	4.5359×10^{-1}
slug (lb-sec ² /ft)	kilogram (kg)	1.4594×10
ton (2000 lbm)	kilogram (kg)	9.0718×10^2
<i>(Moment of force)</i>		
pound-foot (lb-ft)	newton-meter (N·m)	1.3558
pound-inch (lb-in.)	newton-meter (N·m)	0.1129 8
<i>(Moment of inertia, area)</i>		
inch ⁴	meter ⁴ (m ⁴)	41.623×10^{-8}
<i>(Moment of inertia, area)</i>		
pound-foot-second ² (lb-ft-sec ²)	kilogram-meter ² (kg·m ²)	1.3558
<i>(Momentum, linear)</i>		
pound-second (lb-sec)	kilogram-meter/second (kg·m/s)	4.4482
<i>(Momentum, angular)</i>		
pound-foot-second (lb-ft-sec)	newton-meter-second (kg·m ² /s)	1.3558
<i>(Power)</i>		
foot-pound/minute (ft-lb/min)	watt (W)	2.2597×10^{-2}
horsepower (550 ft-lb/sec)	watt (W)	7.4570×10^2
<i>(Pressure, stress)</i>		
atmosphere (std)(14.7 lb/in. ²)	newton/meter ² (N/m ² or Pa)	1.0133×10^5
pound/foot ² (lb/ft ²)	newton/meter ² (N/m ² or Pa)	4.7880×10
pound/inch ² (lb/in. ² or psi)	newton/meter ² (N/m ² or Pa)	6.8948×10^3
<i>(Spring constant)</i>		
pound/inch (lb/in.)	newton/meter (N/m)	1.7513×10^2
<i>(Velocity)</i>		
foot/second (ft/sec)	meter/second (m/s)	$3.048 \times 10^{-1*}$
knot (nautical mi/hr)	meter/second (m/s)	5.1444×10^{-1}
mile/hour (mi/hr)	meter/second (m/s)	$4.4704 \times 10^{-1*}$
mile/hour (mi/hr)	kilometer/hour (km/h)	1.6093
<i>(Volume)</i>		
foot ³ (ft ³)	meter ³ (m ³)	2.8317×10^{-2}
inch ³ (in. ³)	meter ³ (m ³)	1.6387×10^{-5}
<i>(Work, Energy)</i>		
British thermal unit (BTU)	joule (J)	1.0551×10^3
foot-pound force (ft-lb)	joule (J)	1.3558
kilowatt-hour (kw-h)	joule (J)	$3.60 \times 10^6*$

*Exact value

1-5 LAW OF GRAVITATION:

The law of gravitation is expressed by the equation

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

Eq 2

Where :

F = the mutual force of attraction between two particle.

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

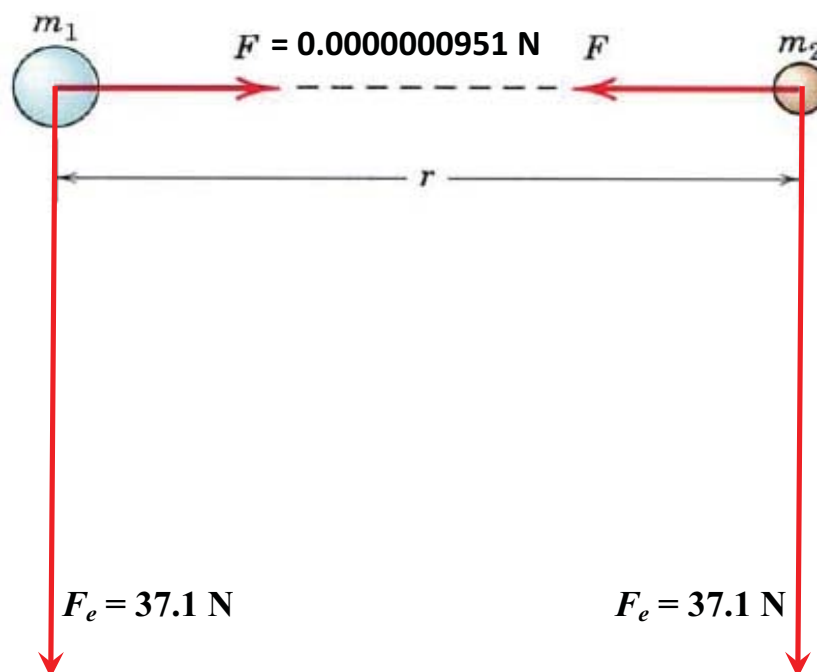
m_1, m_2 = the mass of the two particles.

r = the distance between the centers of the particles.

Gravitational attraction of the earth:

Gravitational forces exist between every pair of bodies on the surface of the earth the only gravitational force of appreciable magnitude is the force due to the attraction of the earth.

For example, each of two iron spheres 100mm in diameter is attracted to the earth with a gravitational force of 37.1 N which is its weight. On the other hand the force of mutual attraction between the spheres is 0.0000000951 N. this force is clearly negligible compared with the earth attraction of 37.1 N.



For body of mass m near the surface of the earth, the gravitational attraction F of the body is specified by (Eq 1). We usually denote the magnitude of this gravitational

ENGINEERING MECHANICS STATIC

force or weight with the symbol (w). Because the body falls with an acceleration g according to Newton's second law:

$$F = m a$$

In this case $F = W$ and $a = g$

Then

$$W = m g \quad \longrightarrow \quad \text{the weight of the body}$$

Where:

W = weight in (N)

m = mass in (kg)

g = Earth acceleration = $9.81 \text{ m/s}^2 = 32.2 \text{ ft/sec}^2$

Ex 1

Determine the weight in Newton's of a car whose mass is 1400 kg. Convert the mass of the car to slugs and then determine its weight in pounds.

Sol

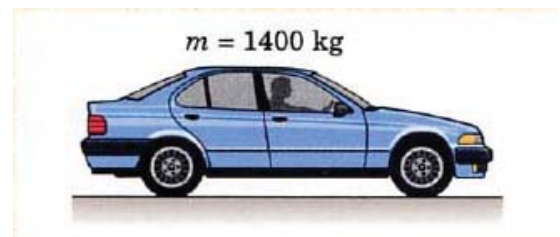
1) $W = m g = 1400 \times 9.81 = 13730 \text{ N}$

2) From the table of conv. $1 \text{ slug} = 14.594 \text{ kg}$

$$m = 1400 \text{ kg} \times \left[\frac{1 \text{ slug}}{14.594 \text{ kg}} \right] = 95.9 \text{ slugs}$$

the weight in pounds is

$$W = m g = 95.9 \times 32.2 = 3090 \text{ lb}$$



Ex 2

Use Newton's law of universal gravitation to calculate the weight of a 70 kg person standing on the surface of the earth. Then repeat the calculation by using $W = m g$ and compare your two results

Sol

$$F = G \times \frac{m_1 m_2}{r^2} = \frac{(6.673 \times 10^{-11}) \times (5.976 \times 10^{24}) \times (70)}{(6371 \times 10^3)^2} = 688 \text{ N}$$

$$W = m g = 70 \times 9.81 = 687 \text{ N}$$

The discrepancy is due to the fact that Newton's universal gravitational law does not take into account the rotation of the earth.

