

12.1 ♣ Two types of forces in a free-body diagram (FBD) (Section 16.5).

From an engineering/FBD perspective, the two types of forces are and .

12.2 ♣ What is 1 Newton and 1 lbf? (Section 19.1).

1 Newton is defined as (circle all that apply)	<input type="checkbox"/> $1 \frac{\text{kg m}}{\text{s}^2}$	<input type="checkbox"/> $9.81 \frac{\text{kg m}}{\text{s}^2}$	<input type="checkbox"/> $32.2 \frac{\text{kg m}}{\text{s}^2}$	<input type="checkbox"/> None of these
1 lbf is defined as or approximately equal to (circle all that apply)	<input type="checkbox"/> $1 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2}$	<input type="checkbox"/> $1 \text{ slug} \cdot \frac{\text{ft}}{\text{s}^2}$	<input type="checkbox"/> $1 \text{ lb}_m \cdot \frac{\text{ft}}{\text{s}^2}$	
	<input type="checkbox"/> $9.81 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2}$	<input type="checkbox"/> $9.81 \text{ slug} \cdot \frac{\text{ft}}{\text{s}^2}$	<input type="checkbox"/> $9.81 \text{ lb}_m \cdot \frac{\text{ft}}{\text{s}^2}$	
	<input type="checkbox"/> $32.2 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2}$	<input type="checkbox"/> $32.2 \text{ slug} \cdot \frac{\text{ft}}{\text{s}^2}$	<input type="checkbox"/> $32.2 \text{ lb}_m \cdot \frac{\text{ft}}{\text{s}^2}$	

Using the exact Section 19.1 NIST conversion factor for lbf to kg and the exact conversion factor $1 \text{ inch} \triangleq 2.54 \text{ cm}$, show how to calculate the conversion factor for lbf to Newton.

Result
 $1 \text{ lbf} \approx \frac{\text{input} \text{ lb}_m \text{ ft}}{\text{s}^2} * \frac{\text{input} \text{ kg}}{\text{lb}_m} * \frac{\text{input} \text{ inch}}{\text{ft}} * \frac{\text{input} \text{ ft}}{\text{input} \text{ ft}} * \frac{\text{input} \text{ ft}}{\text{input} \text{ ft}} * \frac{\text{input} \text{ N}}{\text{kg m/s}^2} \approx 4.45 \text{ N}$

12.3 ♣ Force concepts (Section 16.3).

A force is a well-defined quantity:	True/False
The resultant of a set of forces is a force.	True/False
In the SI (metric) system, the units of force are:	<input type="text"/>
In the SI (metric) system, the units of impulse are:	<input type="text"/>
$\vec{F} = m \vec{a}$ is violated if a non-zero forces exists without the presence of a massive object	True/False
$\vec{F} = m \vec{a}$ is violated if mass exists without the presence of force	True/False

12.4 ♣ Law of action/reaction (Section 16.1).

Circle the forces that obey the law of action/reaction. Explain why each pair obeys/disobeys.

12.5 ♣ Coulomb's friction law (Section 19.6).

The range for Coulomb's coefficient of static friction is always $0 \leq \mu_s \leq 1$. True/False.

Coulomb's friction law is exact/accurate (< 1% error)/approximate/completely wrong.

12.6 ♣ Force and mass concepts (Section 19.1).

The center of mass and center of gravity may be different points.	True/False
The center of gravity of a rigid body always exists.	True/False

12.7 ♣ Convert U.S. units of psi to SI units of Pascals and estimate stress (Section 19.1).

Use each conversion factors (number) below at least once (and others you should know) to convert units of 1 inch to **x** meters, 1 lbf (pound-force) to **y** Newtons, and 1 psi ($\frac{\text{lbf}}{\text{inch}^2}$) to **z** Pascals ($\frac{\text{N}}{\text{m}^2}$). Express results for **z** in terms of the intermediate conversion factors **x** and **y**.

$$1 \text{ inch} \triangleq 2.54 \text{ cm} \qquad 1 \text{ kg} \approx 2.2 \text{ lbf} \qquad 1 \text{ g}_{\text{Earth}} \approx 32.2 \frac{\text{ft}}{\text{s}^2}$$

Conversion Equation (with numbers and units) for calculating result.

1 in = x m	x = 1 in * $\frac{2.54 \text{ cm}}{1 \text{ in}}$ * $\frac{1 \text{ m}}{100 \text{ cm}}$ ≈ 0.0254	Example of how to do units conversions
1 lbf = y N	y = 	≈ 4.45
1 psi = z Pa	z = 	≈ 6894.757 Express z in terms of x and y

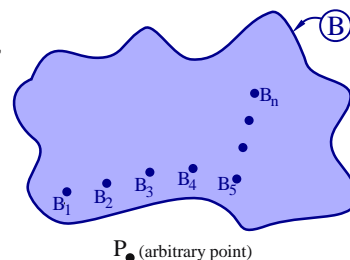
Engineering skill: Estimate/approximate order-of-magnitudes for mass, force, and stress.

Mass of a laptop computer	0.04/0.4/4/40/400 lbf
Weight of a laptop computer	0.04/0.4/4/40/400 lbf
Weight of a laptop computer	0.02/0.2/2/20/200 Newtons
Gage pressure in a bike tire (remember pumping up a bike/car tire?)	0.05/0.5/5/50/500 psi
Gage pressure in a bike tire	0.03/0.3/3/30/300 kPa
Stress of a 200 lbf person on one flat sneaker on a wood floor	0.05/0.5/5/50/500 psi
Stress of a 120 lbf person on one stiletto heel on a wood floor	0.03/0.3/3/30/300 psi

12.8 ♣ Forces on an aluminum body (Sections 16.4, 16.2, and 17.4).

Consider 6.022×10^{23} molecules of aluminum (≈ 27 grams) which define a body **B**. The quantities under investigation (and related moments) are:

- \vec{F}^B the resultant of all forces on **B**
- $\vec{F}_{\text{internal}}^B$ the resultant of all internal forces in **B**
- $\vec{F}_{\text{external}}^B$ the resultant of all external forces on **B**
- \vec{F}^{B_1/B_2} the force on molecule B_1 from molecule B_2



Condition	Static equilibrium?	Circle the following statements that are always true.			
B is rigid	Yes	$\vec{F}^B = \vec{0}$	$\vec{F}_{\text{internal}}^B = \vec{0}$	$\vec{F}_{\text{external}}^B = \vec{0}$	$\vec{F}^{B_1/B_2} = \vec{0}$
		$\vec{M}^{B/P} = \vec{0}$	$\vec{M}_{\text{internal}}^{B/P} = \vec{0}$	$\vec{M}_{\text{external}}^{B/P} = \vec{0}$	$\vec{M}^{\vec{F}^{B_2/B_1}/P} = \vec{0}$
B is flexible (a thin ruler)	Yes	$\vec{F}^B = \vec{0}$	$\vec{F}_{\text{internal}}^B = \vec{0}$	$\vec{F}_{\text{external}}^B = \vec{0}$	$\vec{F}^{B_1/B_2} = \vec{0}$
		$\vec{M}^{B/P} = \vec{0}$	$\vec{M}_{\text{internal}}^{B/P} = \vec{0}$	$\vec{M}_{\text{external}}^{B/P} = \vec{0}$	$\vec{M}^{\vec{F}^{B_2/B_1}/P} = \vec{0}$
B is rigid	No	$\vec{F}^B = \vec{0}$	$\vec{F}_{\text{internal}}^B = \vec{0}$	$\vec{F}_{\text{external}}^B = \vec{0}$	$\vec{F}^{B_1/B_2} = \vec{0}$
		$\vec{M}^{B/P} = \vec{0}$	$\vec{M}_{\text{internal}}^{B/P} = \vec{0}$	$\vec{M}_{\text{external}}^{B/P} = \vec{0}$	$\vec{M}^{\vec{F}^{B_2/B_1}/P} = \vec{0}$
B is molten (liquid metal)	No	$\vec{F}^B = \vec{0}$	$\vec{F}_{\text{internal}}^B = \vec{0}$	$\vec{F}_{\text{external}}^B = \vec{0}$	$\vec{F}^{B_1/B_2} = \vec{0}$
		$\vec{M}^{B/P} = \vec{0}$	$\vec{M}_{\text{internal}}^{B/P} = \vec{0}$	$\vec{M}_{\text{external}}^{B/P} = \vec{0}$	$\vec{M}^{\vec{F}^{B_2/B_1}/P} = \vec{0}$

12.9 ♣ **Measurement accuracies of the Universal Gravitational Constant G** (Section 19.3).

The gravitational force on a particle Q of mass m_Q from a particle P of mass m_P can be written in terms of Q 's position from P as

$$\vec{F}^{Q/P} = \frac{-G m_P m_Q}{|\vec{r}^{Q/P}|^3} \vec{r}^{Q/P} \quad (19.3)$$

What are the dimensions of G (in terms of mass, length and time) and the SI units of G ?

Result: Dimensions of G :
 (in terms of mass, length, time) Units of G :
 (in terms of kg, m, s)

The number of significant digits the first measurement of the “**Universal Gravitational Constant**” G in 1798 by Cavendish and recent (year 2000⁺) experiments of G are estimated to be accurate to:

Experiments in 1798	1	2	5	7	infinite
Experiments in 2000 ⁺	1	2	5	7	infinite

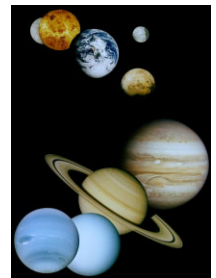
Note: Section 19.3 discusses experiments involving G .

12.10 ♣ **According to Newton’s laws (theories), is the universe static?** (Sections 16.2 and 17.3)

Consider the system S consisting of all matter, life, forces, etc.^a

- Newton’s laws dictates the resultant of all forces on S is $\vec{0}$, i.e., $\vec{F}^S = \vec{0}$. True/False.
- The moment of all forces on S about any point P is $\vec{0}$, i.e., $\vec{M}^{S/P} = \vec{0}$. True/False.
- Newton’s laws dictates the universe is in **static equilibrium**. True/False.
- Newton’s 1st/2nd/3rd law explains my answer? (circle one)

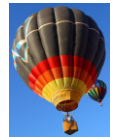
Why:



^a Carbon 12 has $\approx 6.02 \times 10^{23}$ molecules. The universe has $\approx 10^{80}$ molecules.

12.11 ♣ **FBDs (Free-Body Diagrams) for 3D three-balloon system.**

The picture below shows a cup hanging from three light (massless) strings, which attach to a motionless helium-filled balloon. For each system, draw a **FBD** (use the given assumptions).



Helium is lighter than air.

<p><u>FBD of cup:</u></p>	<p><u>FBD of left string:</u></p>	<p><u>FBD of left balloon:</u></p>
<p>Assumptions in FBD</p> <p>Only relevant forces are Earth’s uniform gravity and contact forces from strings (no wind/air resistance, electromagnetic forces, etc.)</p>	<p>Assumptions in FBD</p> <p>String is inextensible. Only relevant forces are tension in string (gravity/other forces are negligible compared to tension.)</p>	<p>Assumptions in FBD</p> <p>Relevant forces are gravity from Earth, fluid pressure from air (buoyancy), and contact from strings and other balloons.</p>