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 lb$_f$? (Section 19.1).

1 Newton is defined as (circle all that apply)	$1\ \frac{\text{kg m}}{\text{s}^2}$	$9.81\ \frac{\text{kg m}}{\text{s}^2}$	$32.2\ \frac{\text{kg m}}{\text{s}^2}$	None of these
1 lb$_\text{f}$ is defined as or approximately equal to (circle all that apply)	$1\ \text{kg}\cdot\frac{\text{m}}{\text{s}^2}$ $9.81\ \text{kg}\cdot\frac{\text{m}}{\text{s}^2}$ $32.2\ \text{kg}\cdot\frac{\text{m}}{\text{s}^2}$	$1\ \text{slug}\cdot\frac{\text{ft}}{\text{s}^2}$ $9.81\ \text{slug}\cdot\frac{\text{ft}}{\text{s}^2}$ $32.2\ \text{slug}\cdot\frac{\text{ft}}{\text{s}^2}$	$1\ \text{lb}_\text{m}\cdot\frac{\text{ft}}{\text{s}^2}$ $9.81\ \text{lb}_\text{m}\cdot\frac{\text{ft}}{\text{s}^2}$ $32.2\ \text{lb}_\text{m}\cdot\frac{\text{ft}}{\text{s}^2}$	

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

Result

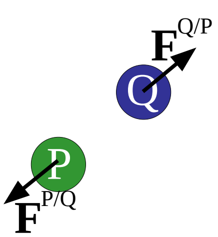
$$1\ \text{lbf} \approx \frac{\square\ \text{lbm ft}}{\text{s}^2} * \frac{\square\ \text{kg}}{\square\ \text{lbm}} * \frac{\square\ \text{inch}}{\square\ \text{ft}} * \frac{\square\ \square}{\square\ \square} * \frac{\square\ \square}{\square\ \square} * \frac{\square\ \text{N}}{\square\ \text{kg m/s}^2} \approx 4.45\ \text{N}$$

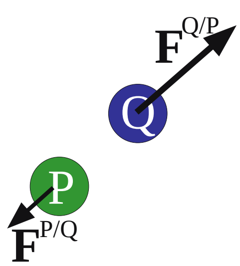
12.3 ♣ Force concepts (Section 16.3).

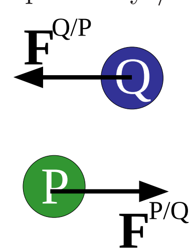
A force is a well-defined quantity:	**True/False**
The resultant of a set of forces is a force.	**True/False**
In the SI (metric) system, the units of force are:	____
In the SI (metric) system, the units of impulse are:	____
$\vec{\mathbf{F}} = m\,\vec{\mathbf{a}}$ is violated if a non-zero forces exists without the presence of a massive object	**True/False**
$\vec{\mathbf{F}} = m\,\vec{\mathbf{a}}$ 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 $0 \le \mu_s \le 1$. **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 $\boldsymbol{x}$ meters, 1 lbf (pound-force) to $\boldsymbol{y}$ Newtons, and 1 psi ($\frac{\text{lbf}}{\text{inch}^2}$) to $\boldsymbol{z}$ Pascals ($\frac{\text{N}}{\text{m}^2}$). Express your results for $\boldsymbol{z}$ in terms of the intermediate conversion factors $\boldsymbol{x}$ and $\boldsymbol{y}$.

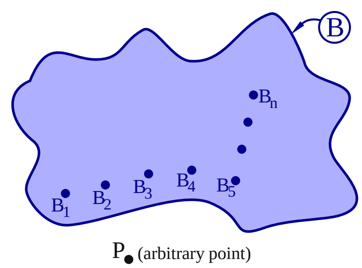
$$1 \text{ inch} \triangleq 2.54 \text{ cm} \qquad 1 \text{ kg} \approx 2.2 \text{ lbm} \qquad 1\, g_{\text{Earth}} \approx 32.2 \frac{\text{ft}}{\text{s}^2}$$

Conversion	Equation (with numbers and units) for calculating result.		
1 in $= \boldsymbol{x}$ m	$\boldsymbol{x} = 1 \text{ in} \ast \frac{2.54 \text{ cm}}{1 \text{ in}} \ast \frac{1 \text{ m}}{100 \text{ cm}} \approx 0.0254$		**Example of how to do units conversions**
1 lbf $= \boldsymbol{y}$ N	$\boldsymbol{y} =$	≈ 4.45	
1 psi $= \boldsymbol{z}$ Pa	$\boldsymbol{z} =$	≈ 6894.757	**Express $\boldsymbol{z}$ in terms of $\boldsymbol{x}$ and $\boldsymbol{y}$**

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

Mass of a laptop computer	**0.04/0.4/4/40/400**	lbm
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:

- $\vec{\mathbf{F}}^{B}$ the resultant of all forces on B
- $\vec{\mathbf{F}}^{B}_{\text{internal}}$ the resultant of all internal forces in B
- $\vec{\mathbf{F}}^{B}_{\text{external}}$ the resultant of all external forces on B
- $\vec{\mathbf{F}}^{B_1/B_2}$ 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	$\vec{\mathbf{F}}^{B} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{external}} = \vec{0}$	$\vec{\mathbf{F}}^{B_1/B_2} = \vec{0}$
		$\vec{\mathbf{M}}^{B/P} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{external}} = \vec{0}$	$\vec{\mathbf{M}}^{\vec{\mathbf{F}}^{B_2/B_1}/P} = \vec{0}$
B is flexible	Yes	$\vec{\mathbf{F}}^{B} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{external}} = \vec{0}$	$\vec{\mathbf{F}}^{B_1/B_2} = \vec{0}$
(a thin ruler)		$\vec{\mathbf{M}}^{B/P} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{external}} = \vec{0}$	$\vec{\mathbf{M}}^{\vec{\mathbf{F}}^{B_2/B_1}/P} = \vec{0}$
B is rigid	No	$\vec{\mathbf{F}}^{B} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{external}} = \vec{0}$	$\vec{\mathbf{F}}^{B_1/B_2} = \vec{0}$
		$\vec{\mathbf{M}}^{B/P} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{external}} = \vec{0}$	$\vec{\mathbf{M}}^{\vec{\mathbf{F}}^{B_2/B_1}/P} = \vec{0}$
B is molten	No	$\vec{\mathbf{F}}^{B} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{F}}^{B}_{\text{external}} = \vec{0}$	$\vec{\mathbf{F}}^{B_1/B_2} = \vec{0}$
(liquid metal)		$\vec{\mathbf{M}}^{B/P} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{internal}} = \vec{0}$	$\vec{\mathbf{M}}^{B/P}_{\text{external}} = \vec{0}$	$\vec{\mathbf{M}}^{\vec{\mathbf{F}}^{B_2/B_1}/P} = \vec{0}$

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 vector from P as

$$\boxed{\vec{\mathbf{F}}^{Q/P} \underset{(19.3)}{=} \frac{-G\, m^P\, m^Q}{|\vec{\mathbf{r}}^{\,Q/P}|^3}\, \vec{\mathbf{r}}^{\,Q/P}}$$

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) $\dfrac{\quad}{\quad}$ Units of G: (in terms of kg, m, s) $\dfrac{\quad}{\quad}$

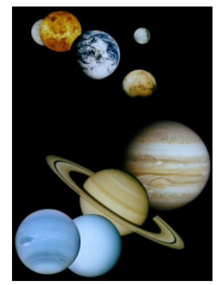
The number of significant digits the first measurement of the "***Universal Gravitational Constant***" G in 1798 by Cavendish and recent (year 2000^+) experiments of G are estimated to be accurate to:

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]

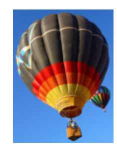


- Newton's laws dictates the resultant of all forces on S is $\vec{\mathbf{0}}$, i.e., $\vec{\mathbf{F}}^S = \vec{\mathbf{0}}$. **True/False**.
- The moment of all forces on S about any point P is $\vec{\mathbf{0}}$, i.e., $\vec{\mathbf{M}}^{S/P} = \vec{\mathbf{0}}$. **True/False**.
- Newton's laws dictates the universe is in **static equilibrium**. **True/False**.
- Newton's **1^{st}/2^{nd}/3^{rd}** 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 ♣ Free-Body Diagrams for 3D three-balloon system.



The picture below shows a cup hanging by strings from three motionless helium-filled balloons. Draw ***FBDs*** of each system for the given assumptions.

Helium is lighter than air.

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