Chapter 12 - Equilibrium and Elasticity

"The time at our disposal each day is elastic; the passions we feel dilate it, those that inspire us shrink it, and habit fills it."

-Marcel Proust

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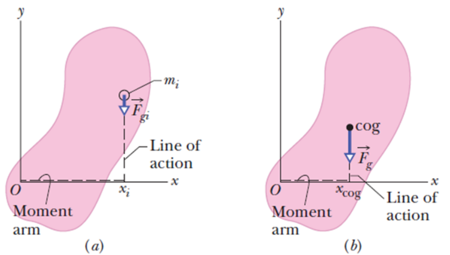
PHYS 211

Center of Gravity

The center of gravity of an object is the point at which the gravitational force acts as if all the mass were concentrated there.



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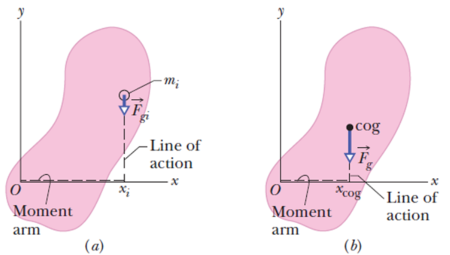
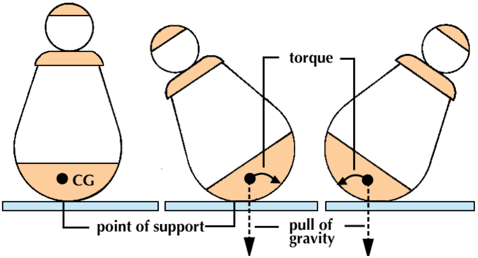


How is this different from center of mass?

Center of Gravity

If the center of gravity is not over the pivot, gravity exerts a torque on the object.



Equilibrium

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An object at rest is in **static** equilibrium.

Equilibrium

Equilibrium implies:

$$\vec{F}_{net} = 0 \text{ and } \vec{\tau}_{net} = 0$$

In components:

$$F_x = 0 \qquad \tau_x = 0$$

$$F_y = 0 \qquad \tau_y = 0$$

$$F_z = 0 \qquad \tau_z = 0$$

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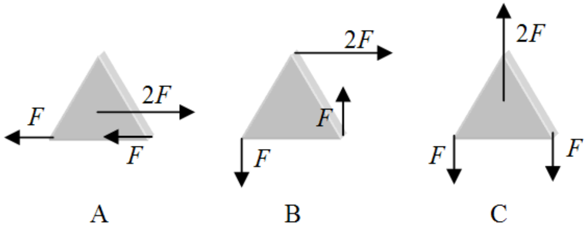
In static equilibrium: $\vec{P} = \vec{L} = 0$.

Equilibrium

Lecture Question 12.2

Which figure(s) below are in static equilibrium?



(a) A only

(b) B only

(c) C only

(d) A and C

(e) A and B

Elasticity

Not all static problems can be determined from the conditions of equilibrium.

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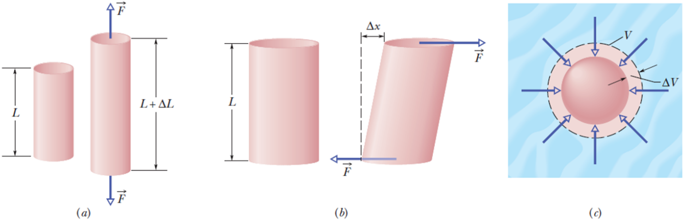
When an object is deformed we must consider the **elasticity** of an object.

Elasticity

There are two concepts for elastic objects:

- **Stress**: the deforming force per unit area (N/m^2)
- **Strain**: the resulting deformation from stress (unitless)



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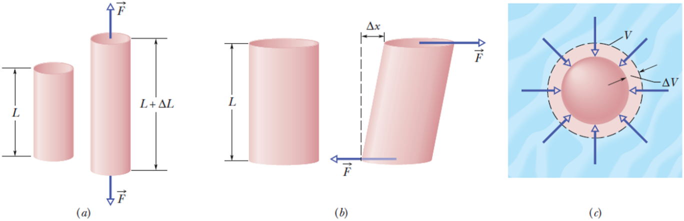

For stress, think "press."

Elasticity

For tension and compression of an object:

$$\text{Stress: } \frac{F}{A} \qquad \text{Strain: } \frac{\Delta L}{L}$$

Elasticity

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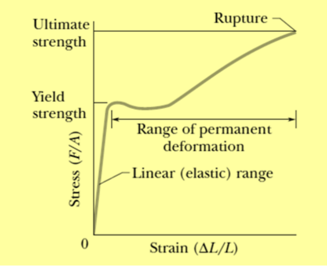
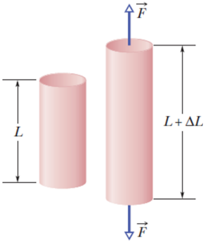
How are these related for a typical material?



Elasticity

The constant of proportionality between Stress and Strain for compression/tension is known as **Young's modulus**.

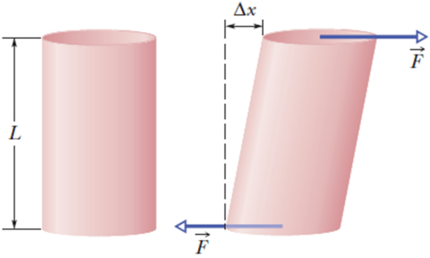
$$\frac{F}{A} = E\frac{\Delta L}{L}$$



Elasticity

The constant of proportionality between Stress and Strain for shearing is known as the **shear modulus**.

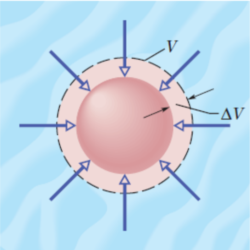
$$\frac{F}{A} = G\frac{\Delta x}{L}$$



Elasticity

The constant of proportionality between Stress and Strain for hydraulic pressure is known as the **bulk modulus**.

$$\frac{F}{A} = p = B\frac{\Delta V}{V}$$



Elasticity

Table 12-1

Some Elastic Properties of Selected Materials of Engineering Interest

Material	Density ρ (kg/m^3)	Young's Modulus E (10^9 N/m^2)	Ultimate Strength S_u (10^6 N/m^2)	Yield Strength S_y (10^6 N/m^2)
Steel[a]	7860	200	400	250
Aluminum	2710	70	110	95
Glass	2190	65	50[b]	—
Concrete[c]	2320	30	40[b]	—
Wood[d]	525	13	50[b]	—
Bone	1900	9[b]	170[b]	—
Polystyrene	1050	3	48	—

[a]Structural steel (ASTM-A36).

[b]In compression.

[c]High strength

[d]Douglas fir.

Lecture Question 12.3

A 1.00-m long wire with a diameter of 0.02 m stretches by 0.03 m when a 20000-N force is applied to one end as the other is held fixed. Consider an identical wire, except that it has a length of 2.00 m. If a 20000-N force is applied to it, how much will this new wire stretch?

(a) 0.06 m
(b) 0.015 m
(c) 0.0075 m
(d) 0.12 m
(e) 0.03 m