

Lectures: Physics 3306

Provides an introduction to a wide variety of topics in classical (pre-quantum) physics as a bridge to prepare students for subsequent upper-level courses in physics. The topics covered include thermodynamics, fluid mechanics, mechanical waves, optics, radiation, electromagnetic phenomena, atoms, and laboratory techniques. Prerequisites: C- or better in PHYS 1106; and in PHYS 1304 or PHYS 1308.

Saptaparna Bhattacharya

January 30th, 2026

Based on Simon Dalley's lectures taught in Spring 2025

Labs

Lectures

Schedule

No class

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January	19	20	21	22	23	24	25
	26 ❄️☁️❄️❄️❄️	27	28 ❄️☁️❄️❄️❄️	29	30	31	1
February	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	1
March	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
April	30	31	1	2	3	4	5

Labs

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May	27	28	29	30	1	2	3
	4	5	6	7	8	9	10

Quick recap

Dimensional Analysis Exercise

- What is the time period of a simple pendulum?

- for small angles?

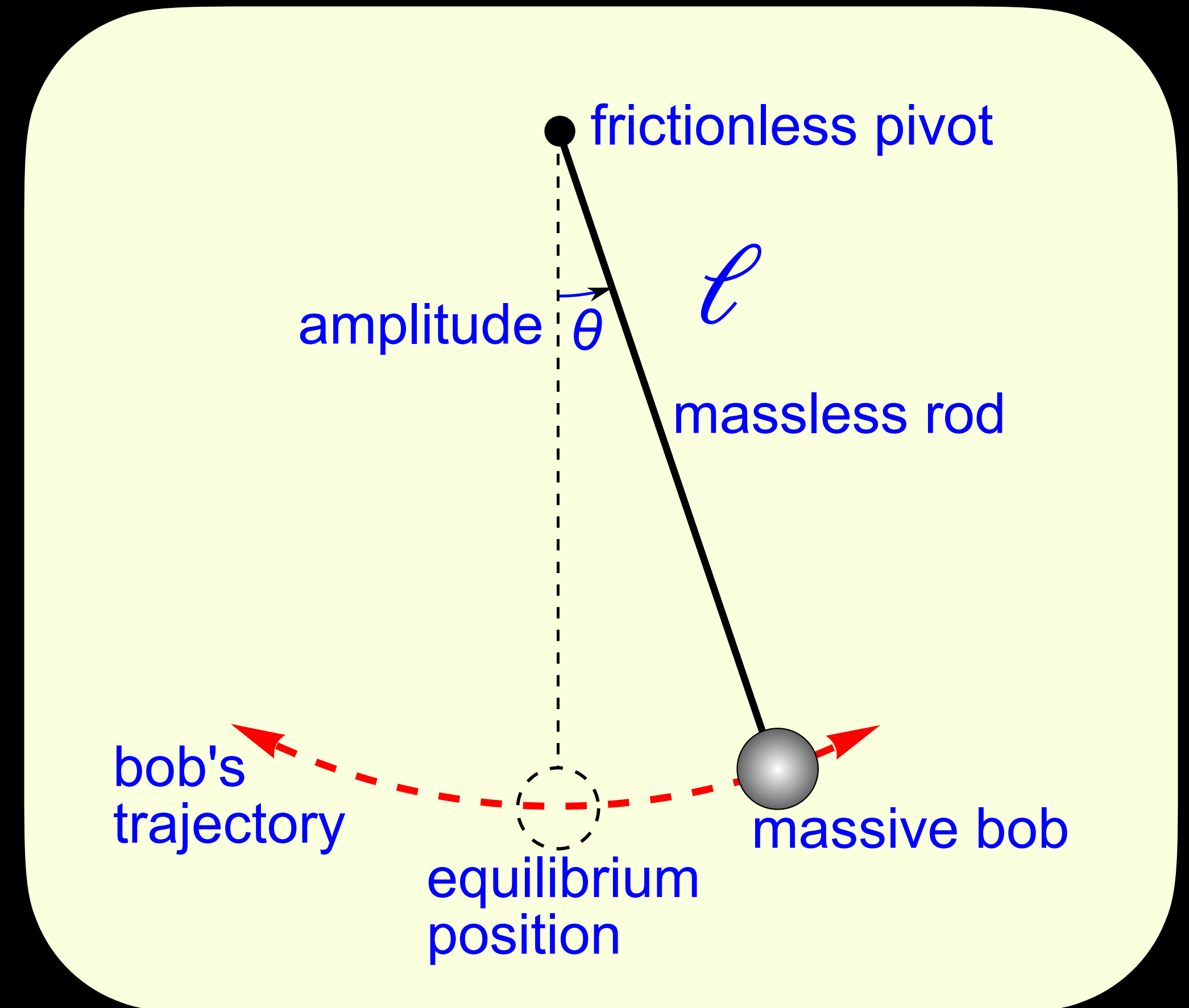
- $T = 2\pi\sqrt{\frac{\ell}{g}}$

- Can the formula below be right?

- $T = 2\pi\left(\frac{\ell}{g}\right)^{1/3}$

- Can terms in the exponent have units?

- $N = N_0e^{-kx}$



Conditions for equilibrium

- The translational motion of a body governed by Newton's law is:

- $\vec{F}_{net} = \frac{d\vec{P}}{dt}$

- A body is in translational equilibrium if:

- $\vec{F}_{net} = 0$

Conditions for equilibrium

- The net force should be zero:
 - $F_{net,x} = 0$
 - $F_{net,y} = 0$
 - $F_{net,z} = 0$

Conditions for equilibrium and definition of torque

- The rotational motion of a body governed by Newton's law is:

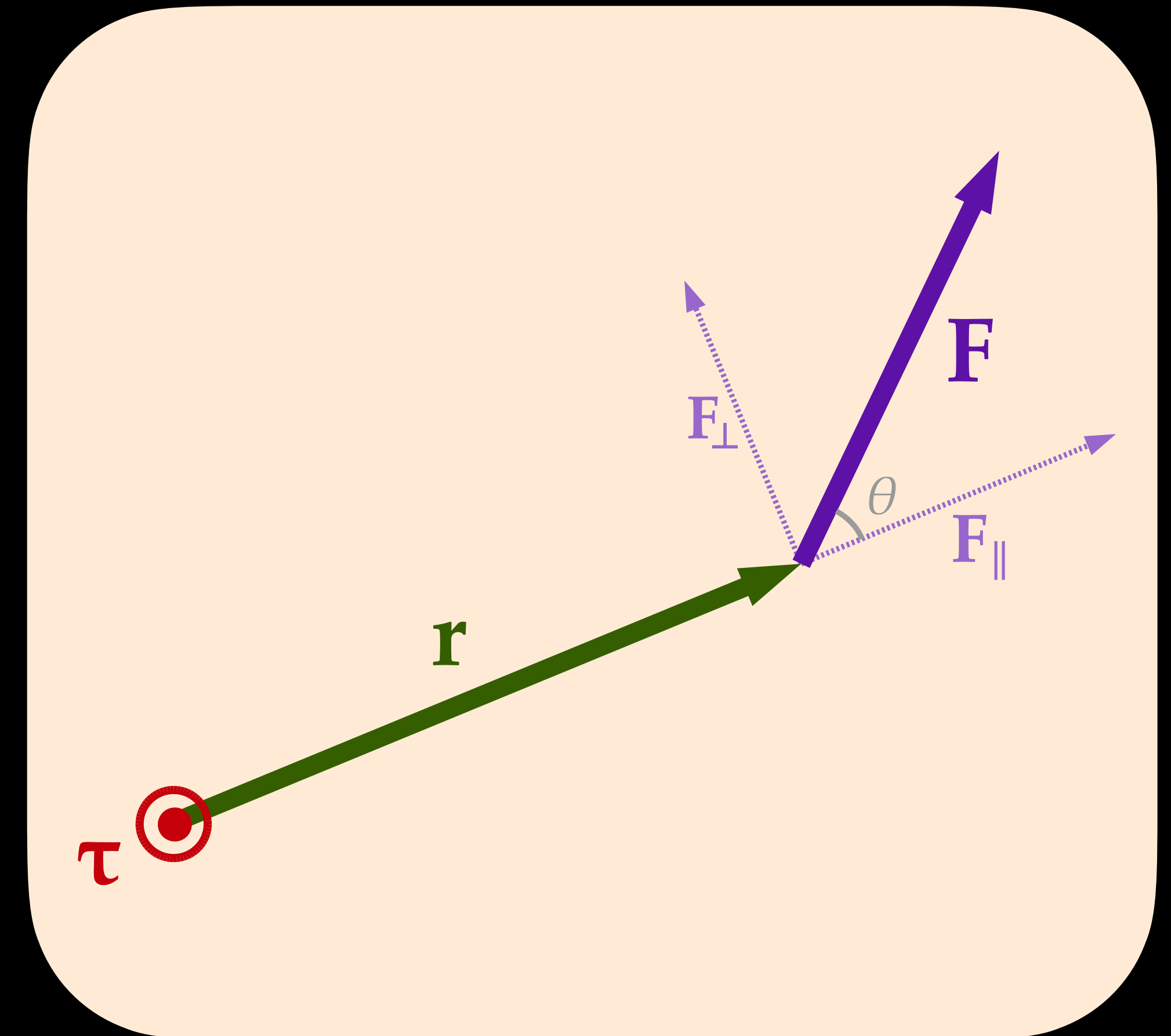
- $$\vec{\tau}_{net} = \frac{d\vec{L}}{dt}$$

- A body is in rotational equilibrium if:

- $$\vec{\tau}_{net} = 0, \tau_{net,x} = 0, \tau_{net,y} = 0, \tau_{net,z} = 0$$

- Torque is the measure of a force's tendency to cause an object to rotate around an axis, acting as the rotational equivalent of linear force

- Defined as the product of the applied force (F) and the perpendicular distance (r) from the axis of rotation to the line of action of the force
($\tau = rF \sin \theta$)



Conditions for equilibrium and definition of torque

- The rotational motion of a body governed by Newton's law is:

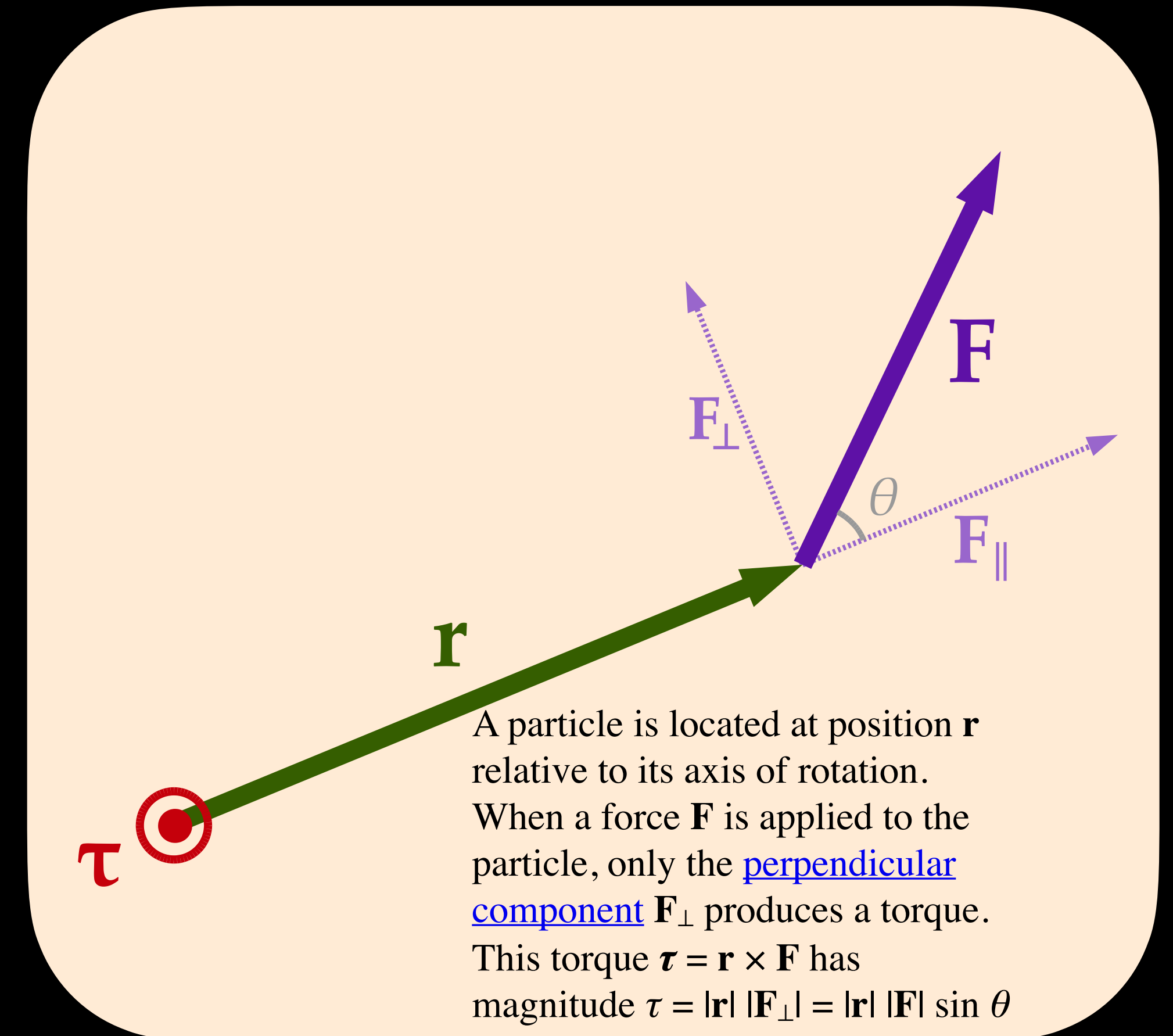
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Center of gravity

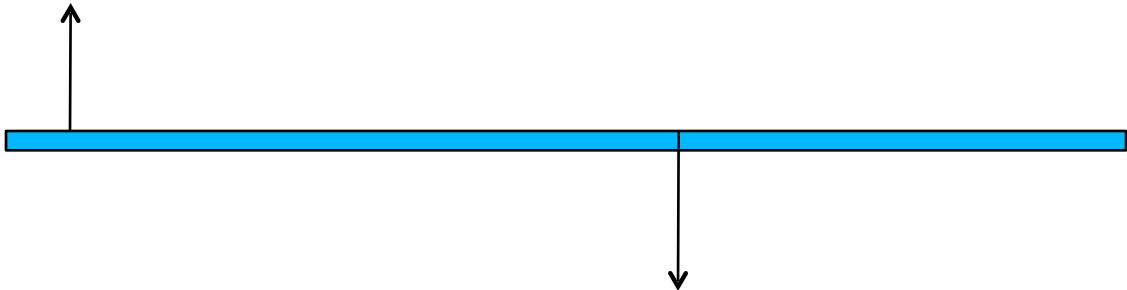
- The gravitational force \vec{F}_g on a body effectively acts on a single point called the center of gravity (cog) of the body
- At each point:
 - $\tau_i = x_i F_{gi}$
- Sum: $\tau_{net} = \sum \tau_i = \sum x_i F_{gi}$
- As a whole, using the concept of center of gravity:
 - $\tau = x_{cog} F_g$
 - $\tau = x_{cog} \sum F_{gi}$
- Equate: $x_{cog} \sum F_{gi} = \sum x_i F_{gi}$
- Substitute: $x_{cog} \sum m_i g_i = \sum x_i m_i g_i$
- Cancel g , $x_{cog} \sum m_i = \sum x_i m_i$, $x_{cog} = \frac{1}{M} \sum x_i m_i$

Equilibrium

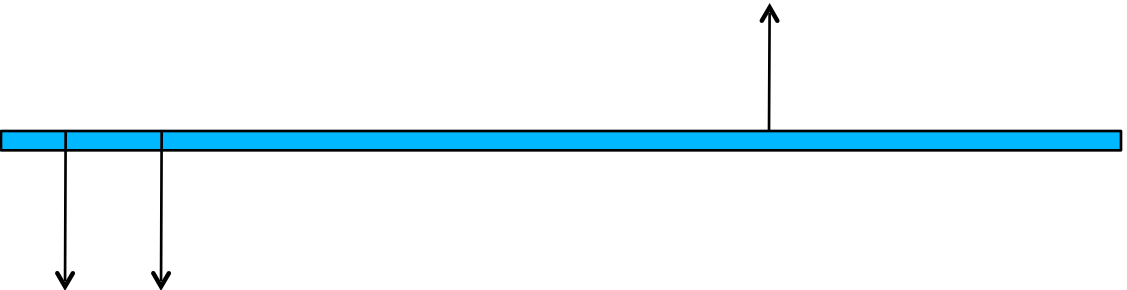
(12-2)

Overhead views of rods are shown with non-zero forces acting on them. Which rod(s) can be in equilibrium if the force magnitudes are adjusted appropriately?

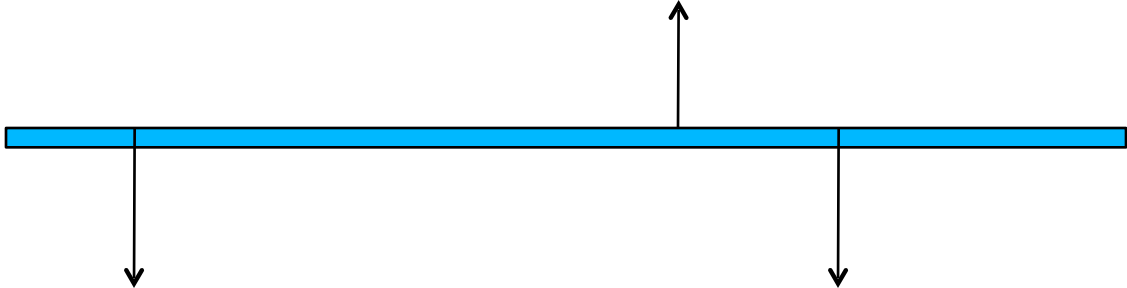
a



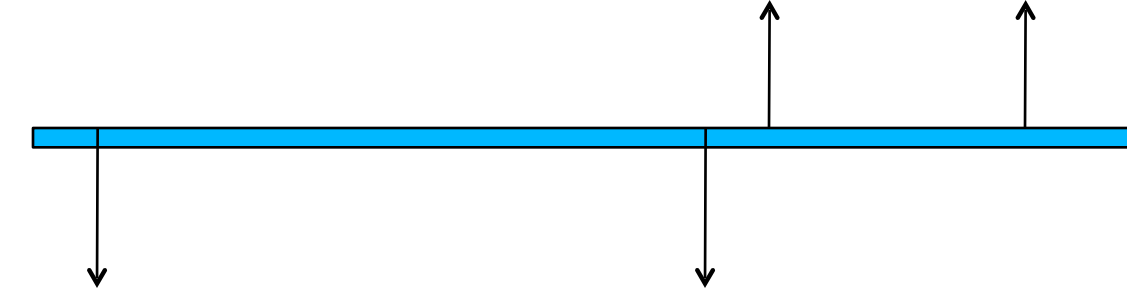
b



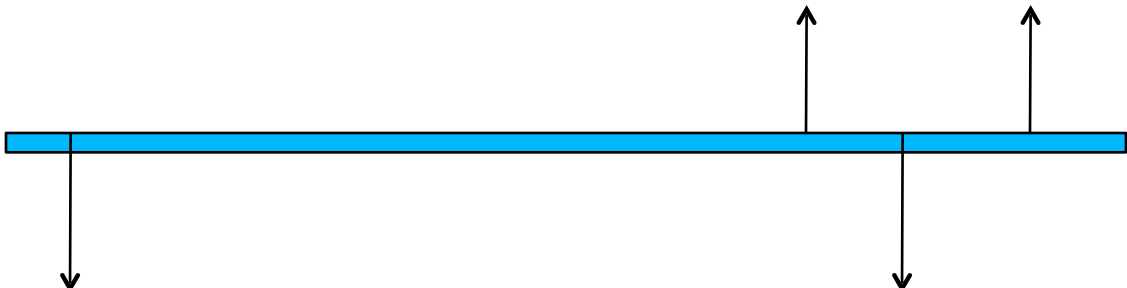
c



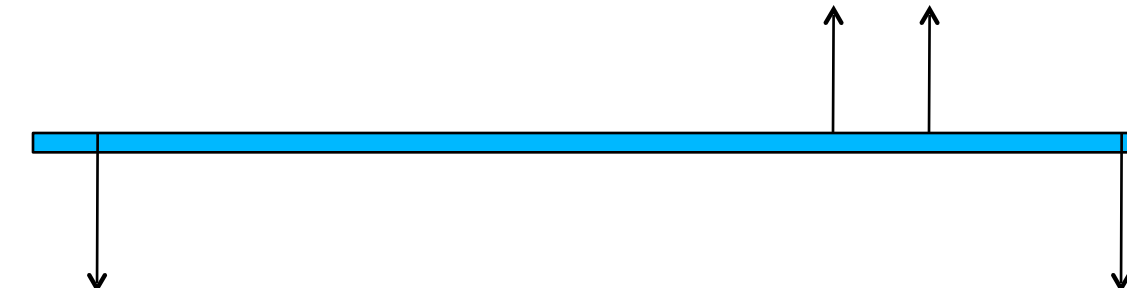
d



e

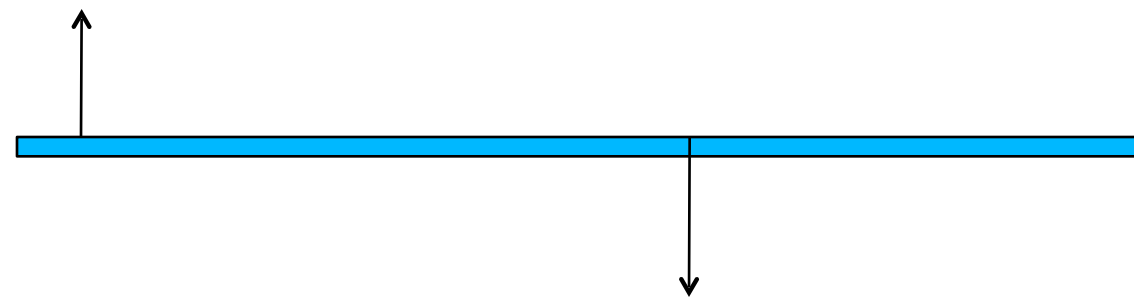


f

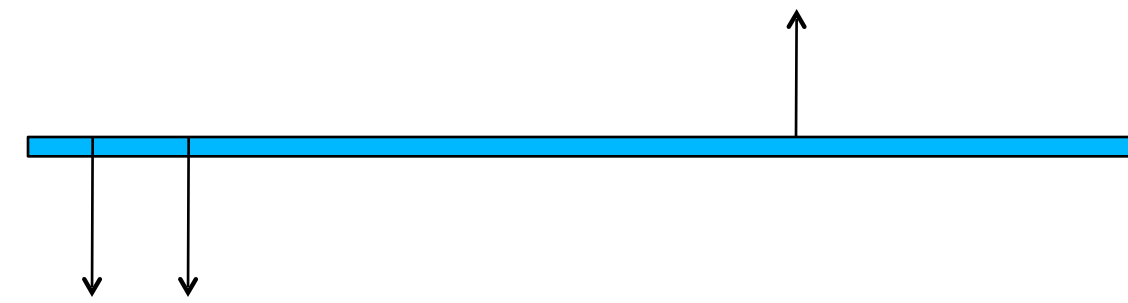


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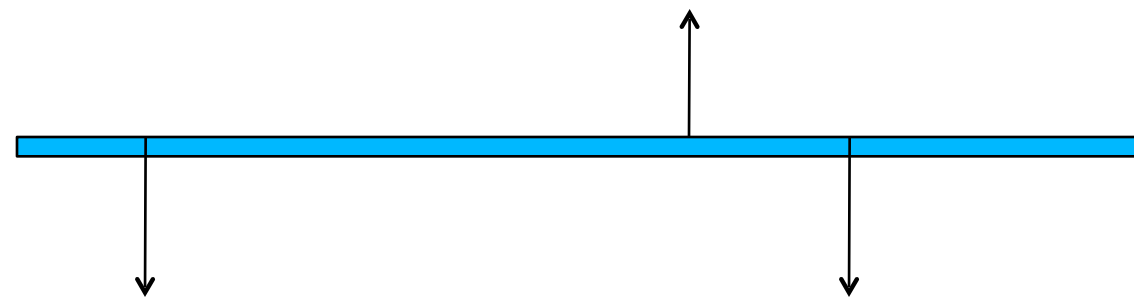
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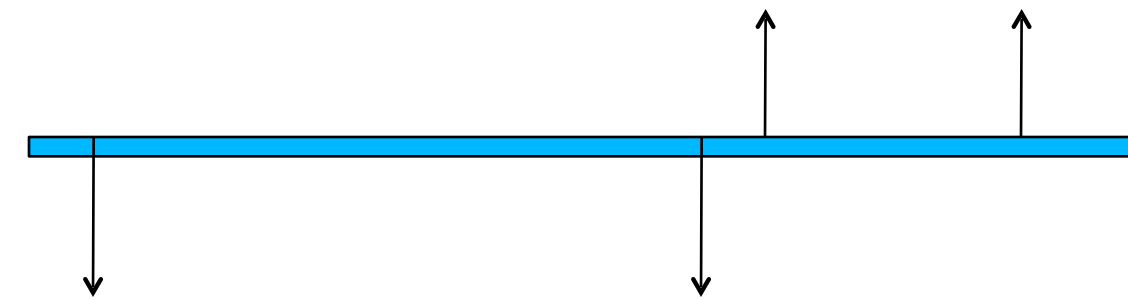
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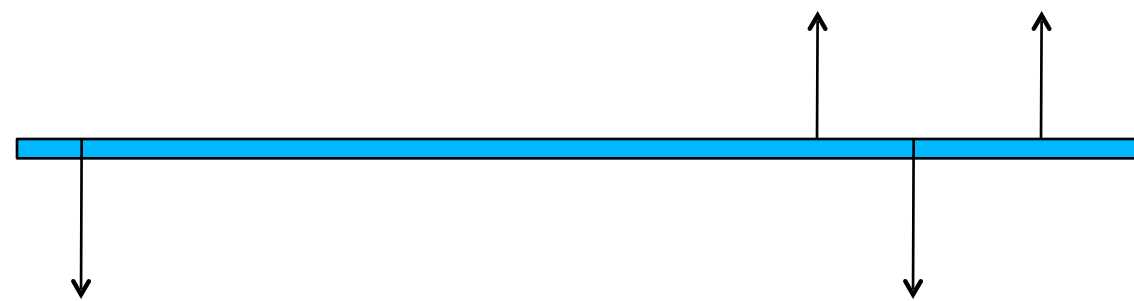
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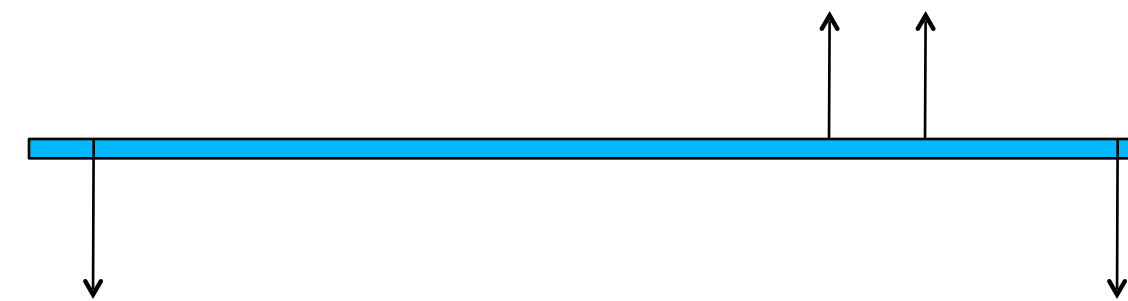
d



e



f



Scenario a:

- **Net force:** Can be zero if magnitudes are equal
- **Net torque:** Both forces produce a clockwise torque about the center. **Result: No.**

Scenario b:

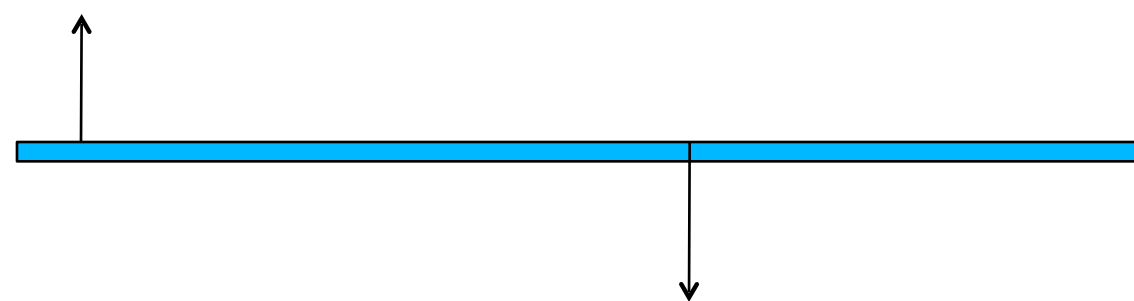
- **Net force:** Can be zero
- **Net torque:** All forces produce a counter-clockwise torque about the center of the rod. **Result: No.**

Scenario c:

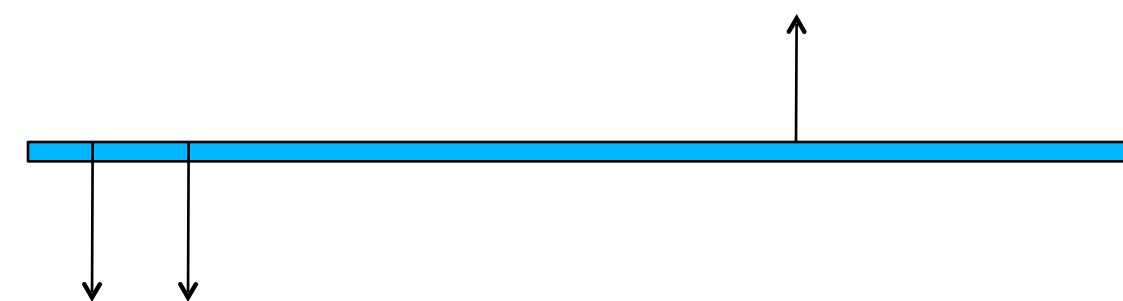
- **Net force:** Can be zero if $F_{up} = F_{down1} + F_{down2}$
- **Net torque:** The downward force on the left creates counter clockwise torque; the downward force on the right creates clockwise torque. These can balance. **Result: Yes**

Overhead views of rods are shown with non-zero forces acting on them. Which rod(s) can be in equilibrium if the force magnitudes are adjusted appropriately?

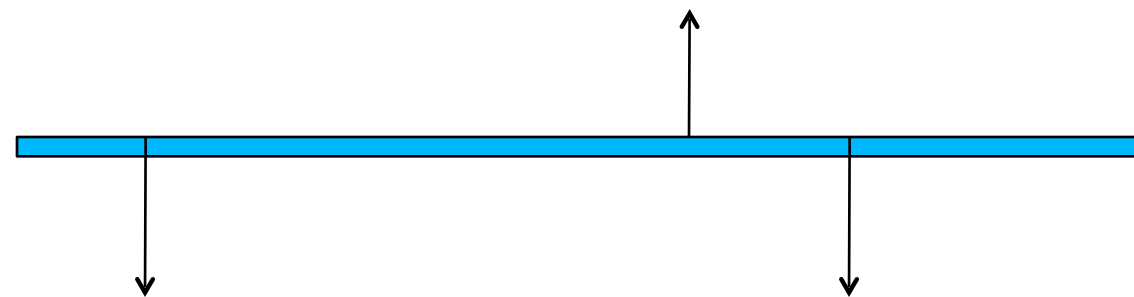
a



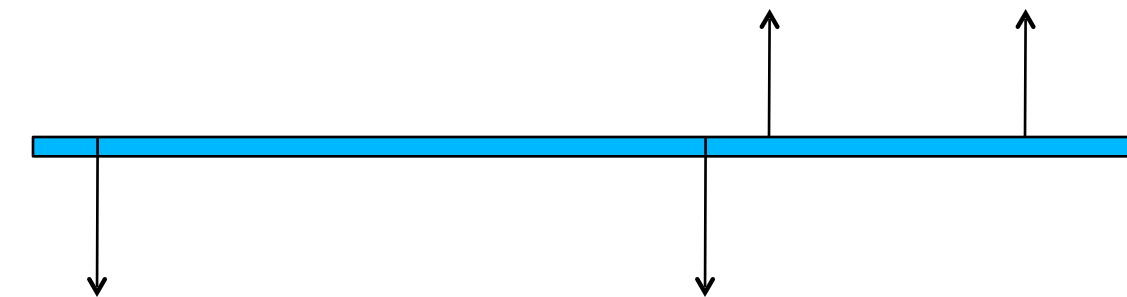
b



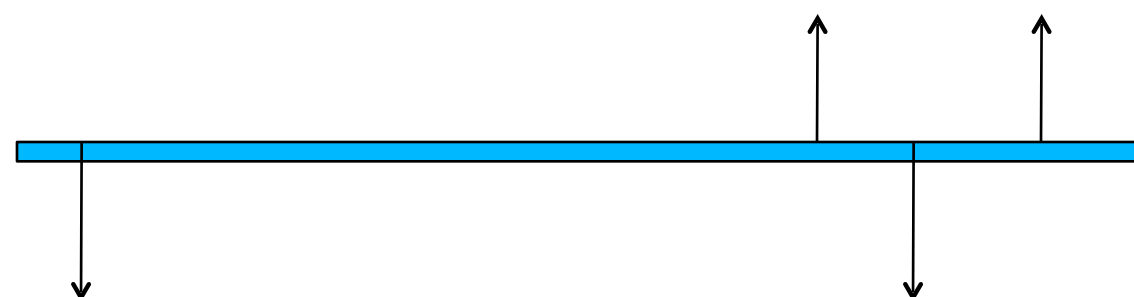
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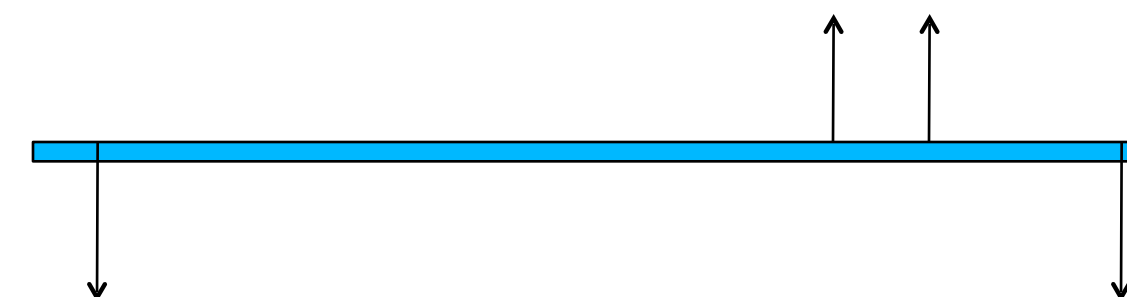
d



e



f



Scenario d:

- **Net force:** Can be zero
- **Net torque:** Every force in this configuration contributes to a clockwise rotation about the center. **Result: No.**

Scenario e:

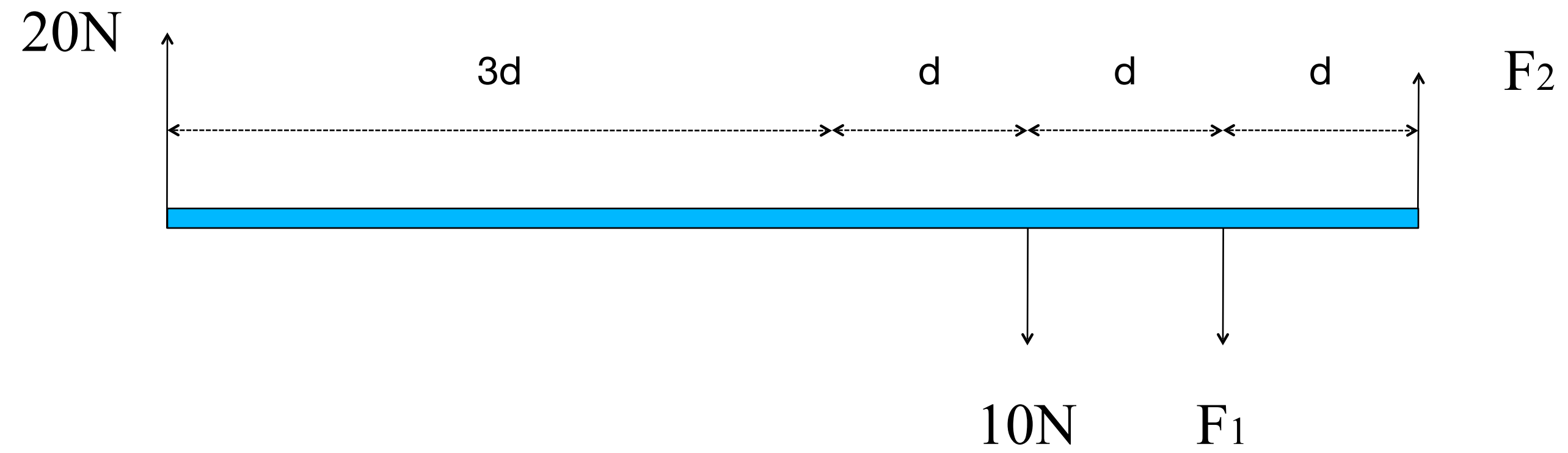
- **Net force:** Can be zero
- **Net torque:** You have forces on both sides of the center providing both clockwise and counterclockwise torques. **Result: Yes.**

Scenario f:

- **Net force:** Can be zero
- **Net torque:** Similar to (c), the symmetric placement of upward and downward forces allows for the torques to cancel out. **Result: Yes.**

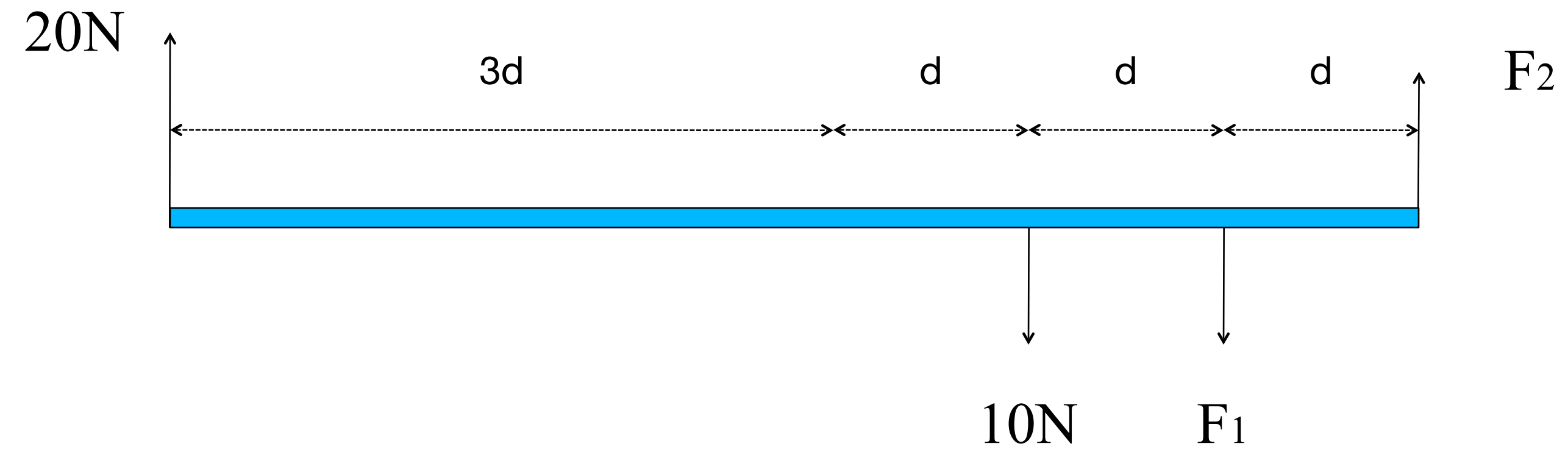
Overhead view of a uniform rod in static equilibrium.

Can you find the magnitudes of the forces F_1 and F_2 from force equilibrium alone?



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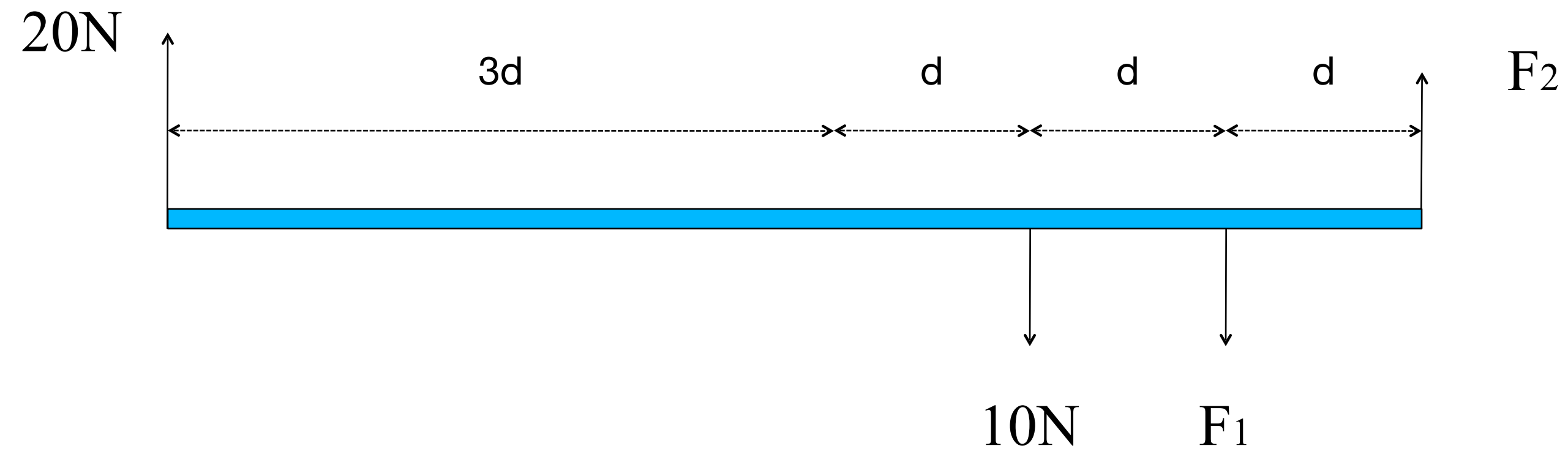


$$20 - 10 - F_1 + F_2 = 0$$

No!

Overhead view of a uniform rod in static equilibrium.

Can you find the magnitudes of the forces F_1 and F_2 from force equilibrium alone?



Forces

$$20 - 10 - F_1 + F_2 = 0$$

Torques

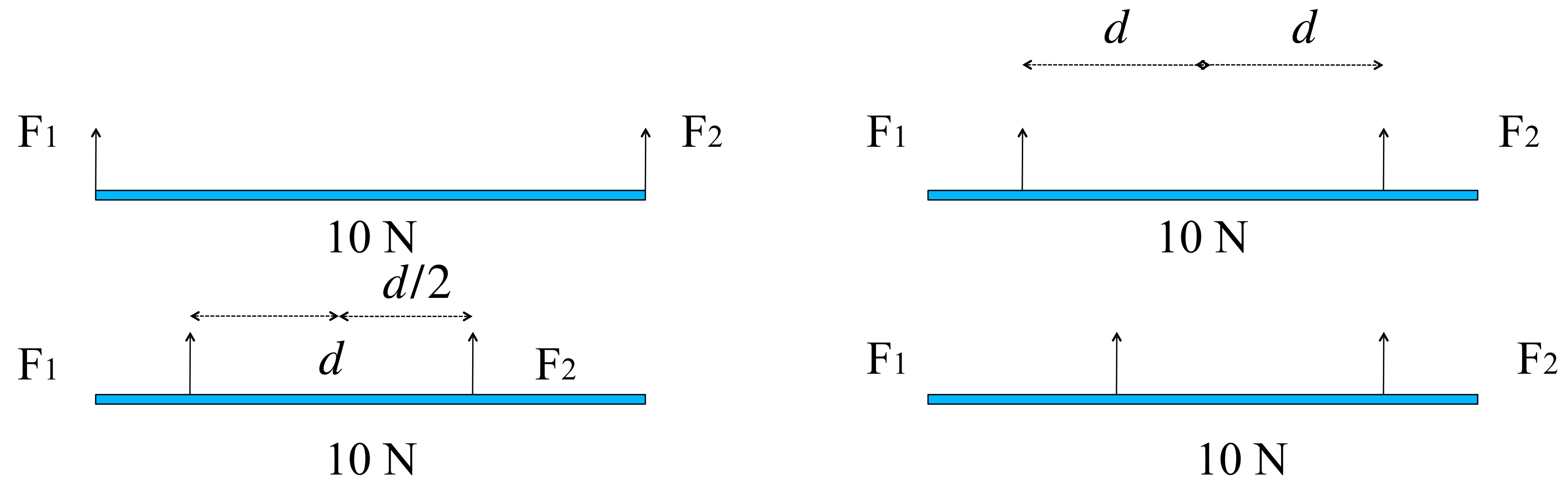
Ex. Place origin at F_1

Anti-Clockwise +

$$-5d \cdot 20 + d \cdot 10 + d \cdot F_2 = 0 \quad \Rightarrow \quad F_2 = 90 \text{ N} \quad \Rightarrow \quad F_1 = 100 \text{ N}$$

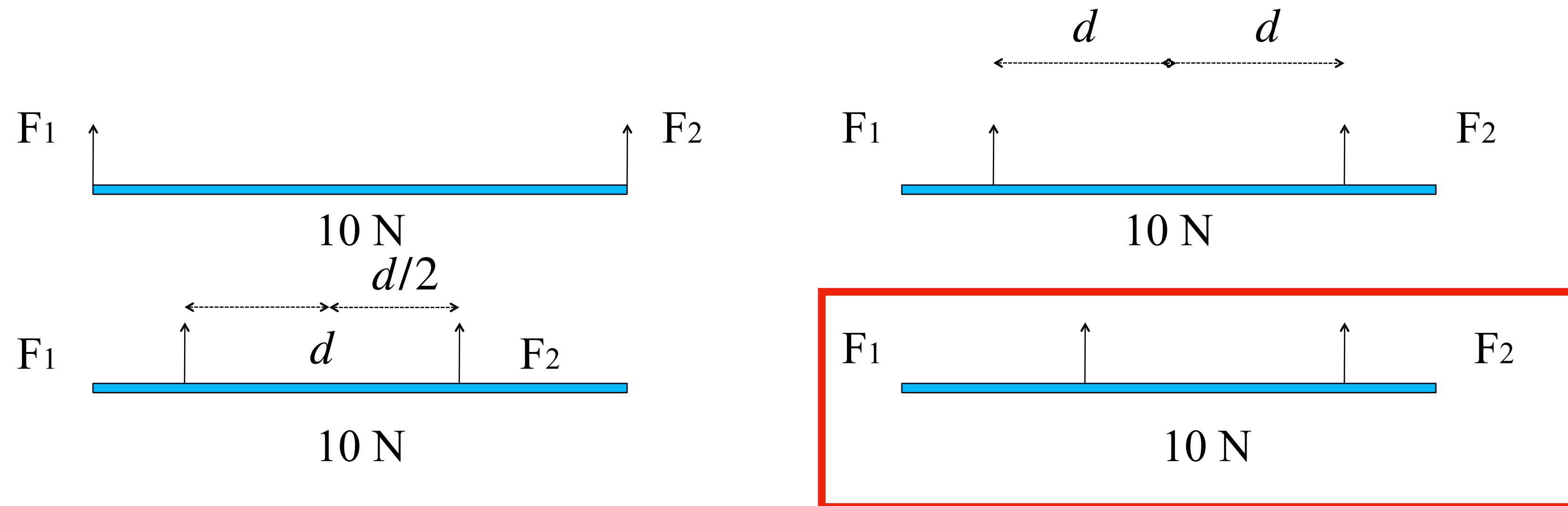
A uniform bar of weight 10 N is suspended by two wires under tension F_1 and F_2 . The horizontal arrows measure to the middle.

In which arrangement are the tensions indeterminate?



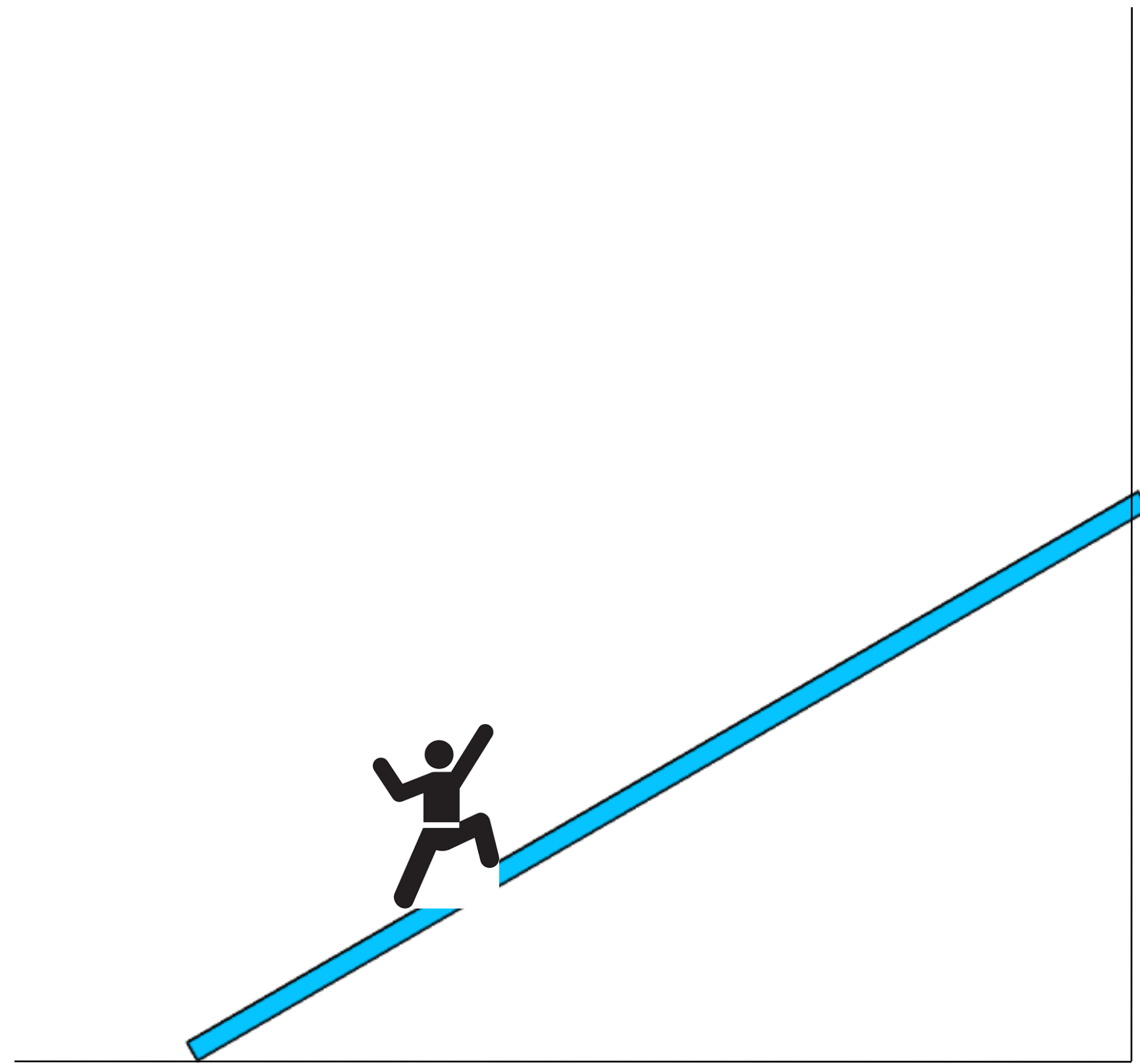
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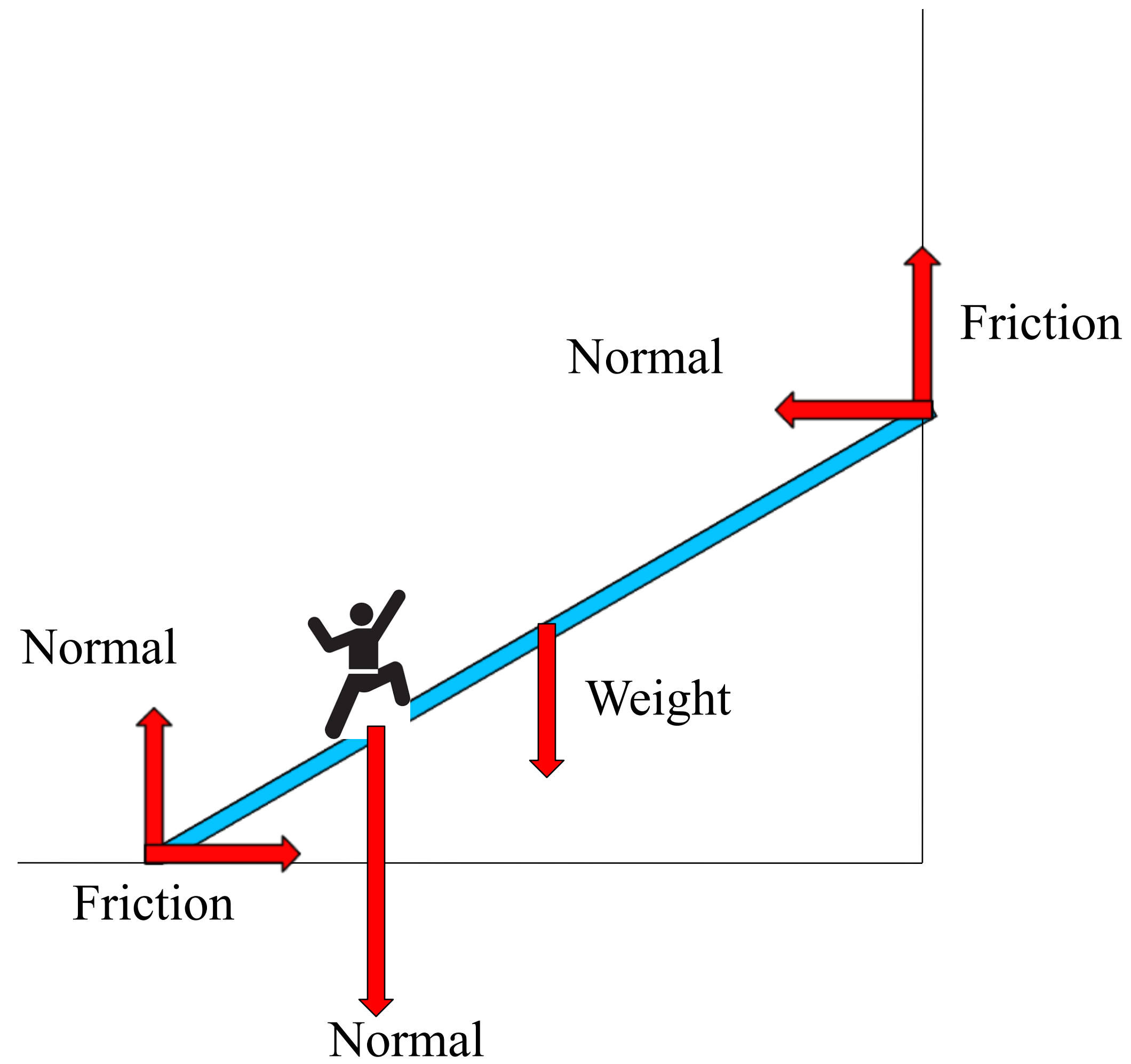


- **Net force:** Can be zero
- **Net torque:** hard to calculate, no easy pivot point that can be defined

Add to the diagram all the macroscopic forces and their types that may act on the heavy rigid uniform ladder (**the thing in blue**).



Add to the diagram all the macroscopic forces and their types that may act on the heavy rigid uniform ladder.



Elasticity

(12-3)

Key Concepts

- Three elastic moduli are used to describe the elastic behavior (deformations) of objects as they respond to forces that act on them
 - Hooke's law: The strain (fractional change in length) is linearly related to the applied stress (force per unit area) by the proper modulus:
 - Stress = modulus X strain
 - When an object is under tension or compression, the stress-strain relation is written as:

- $\frac{F}{A} = E \frac{\Delta L}{L}$, where $\frac{\Delta L}{L}$ is the tensile or compressive strain of the object, F is the magnitude of the applied force \vec{F} causing the strain, A is the cross sectional area over which \vec{F} is applied (perpendicular to A), and E is the Young's modulus for the object. The stress is $\frac{F}{A}$

Key Concepts

- Focusing on the equation:

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

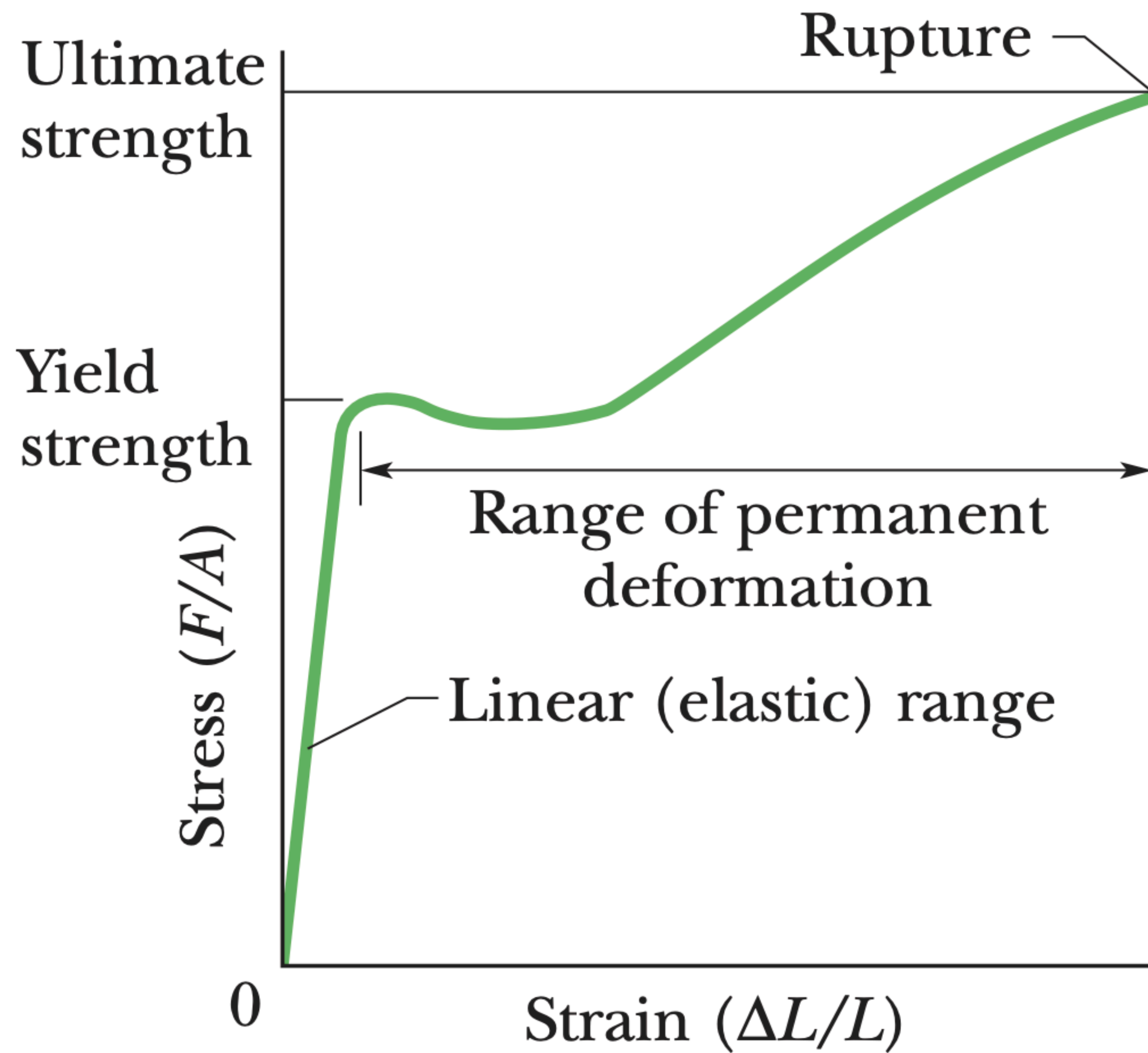
- Stress = modulus X strain

In an plastic deformation region, the gradient of the stress-strain curve

- a) Is always positive
- b) Is always negative
- c) Is always both positive and negative
- d) May be positive or negative in places

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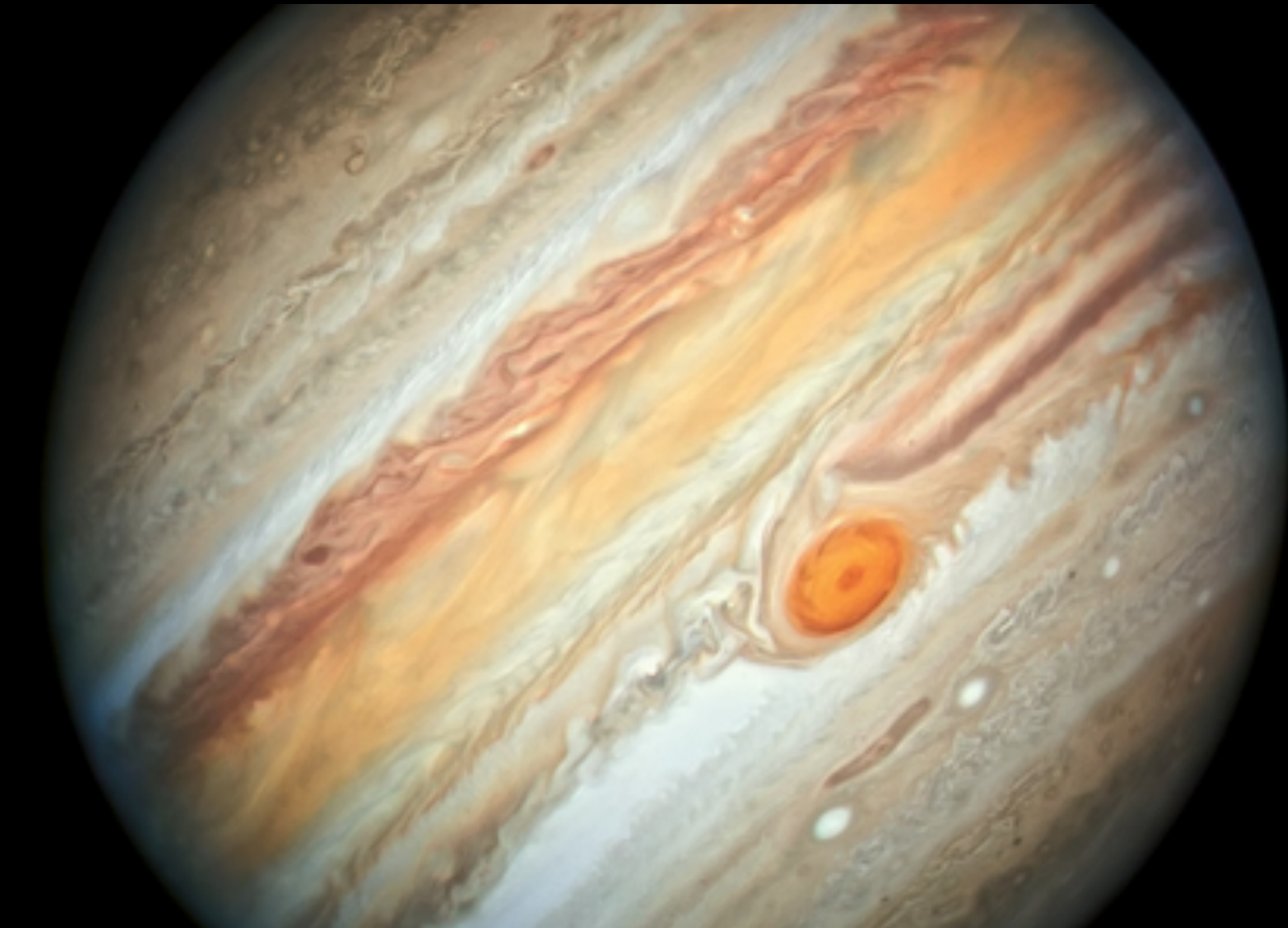


Which of the following relations is stated in Hooke's law?

- a) Stress and strain are proportional to each other
- b) Stress and strain are inversely proportional to each other
- c) Square of strain is directly proportional to stress
- d) Square of strain is inversely proportional to stress

Robert Hooke

- What did he do?



Known for

Balance spring
Conical pendulum
Constant force escapement
Cymatics
Discovery of Gamma Arietis
Discovery of cell
Discovery of Great Red Spot
Hooke's law
Hooke's joint
Hooke's instrument
Hooke's wheel
Micrographia
Microscopy
Portable camera obscura
Reticle
Schlieren
Shadowgraph
Structural coloration
Sash window
Tin can telephone

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Which among the following is the correct SI unit for the Young (or elastic) Modulus?

a) N/m

b) N/m³

c) N/m²

d) N

e) No units

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