Name: ____________________ **Date:** ____________________ **Period:** ____________________

ROTATION DAY 4: STATIC EQUILIBRIUM

Warm-Up (3 min): A uniform beam (weight 200 N, length 3.0 m) rests on a single support.

(a) Where must the support be placed for the beam to balance? ____________________

(b) Now a 100 N weight is hung from the right end. The support stays in the middle. Does the beam tip? Which way? ____________________

(c) What could you do to restore balance WITHOUT moving the support? ____________________

TWO CONDITIONS FOR EQUILIBRIUM

STATIC EQUILIBRIUM

For an object to be in static equilibrium:

Condition 1 (Translational): $\sum F_x = 0$ and $\sum F_y = 0$

→ no net force = no acceleration

Condition 2 (Rotational): $\sum \tau = 0$ about ANY point

→ no net torque = no angular acceleration

Both must be satisfied simultaneously.

Smart Pivot Choice: You can choose ANY pivot point for the torque equation. The best choice eliminates unknowns — pick a point where an unknown force acts, and that force produces zero torque (because $r = 0$).

Physics in the Wild: Why Cranes Don't Tip Over

A tower crane has a long boom lifting heavy loads and a short back-arm loaded with concrete counterweights. The pivot is the tower itself. Engineers calculate $\sum \tau = 0$ for every single lift to make sure the counterweight torque balances the load torque. When they get it wrong, the crane tips — search "crane collapse" and you'll see statics failure in action.

Your ladder problem on page 3 uses the exact same physics.

STATICS PROBLEM-SOLVING STRATEGY

1. Draw a free-body diagram showing ALL forces and where they act
2. Choose a coordinate system (up = $+y$, right = $+x$)
3. Choose a pivot point (pick where an unknown force acts to eliminate it)
4. Write $\sum F_x = 0$, $\sum F_y = 0$, and $\sum \tau = 0$
5. Solve the system of equations

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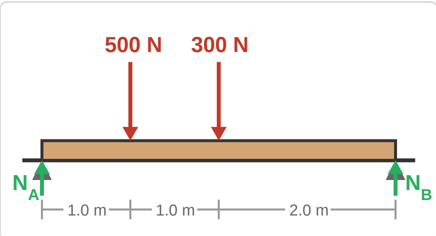
ROTATION DAY 4: STATIC EQUILIBRIUM

WE DO

Beam on Two Supports

A uniform 4.0 m beam weighing 300 N is supported at both ends (A on left, B on right). A 500 N load sits 1.0 m from the left end.



(a) Pivot at A: Write $\sum \tau_A = 0$ to find N_B.

(b) Force balance: Use $\sum F_y = 0$ to find N_A.

(c) Check: Do $N_A + N_B = 300 + 500 = 800$ N? _____ (Verify that all forces are balanced.)

YOU DO

Off-Center Load

Same beam (4.0 m, 300 N). Now the 500 N load moves to 3.0 m from the left end. Find both support forces.

(a) Pivot at A: Find N_B.

(b) Force balance: Find N_A.

(c) Compare: How did moving the load change the support forces?

Name: ______________ Date: ______________ Period: ______________

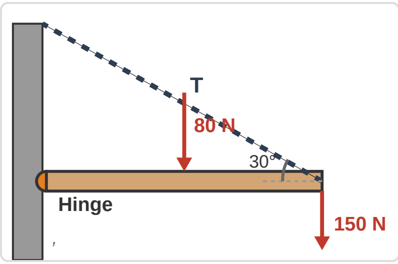
ROTATION DAY 4: STATIC EQUILIBRIUM

HANGING SIGNS & ANGLED SUPPORTS

WE DO

Shop Sign with Cable Support

A 2.0 m horizontal beam is attached to a wall with a hinge at the left end. A cable connects the right end to the wall above the hinge at 30° above horizontal. A 150 N sign hangs from the right end. The beam weighs 80 N.



(a) Pivot at hinge: Write $\sum \tau = 0$ to find cable tension T.

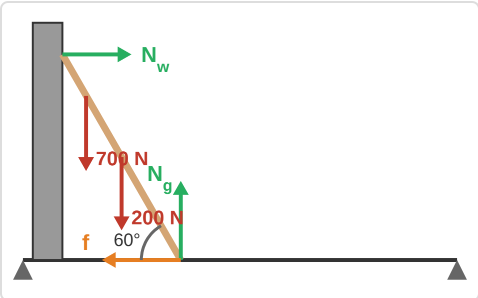
(b) Force balance: $\sum F_x = 0$ to find H_x.

(c) Force balance: $\sum F_y = 0$ to find H_y.

YOU DO

Ladder Against Wall

A 5.0 m ladder (weight 200 N) leans against a frictionless wall at 60° to the ground. A 700 N person stands 4.0 m up the ladder.



(a) Pivot at the ground contact point: Write $\sum \tau = 0$ to find the normal force from the wall, N_w.

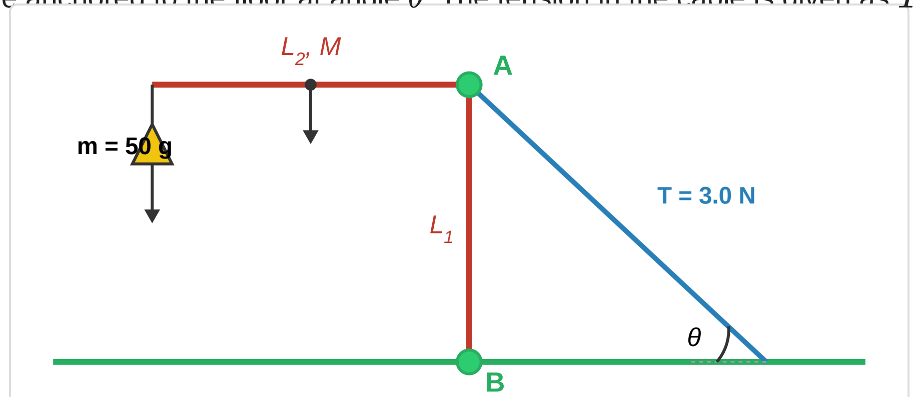
(b) Horizontal force balance: Find the friction force f at the ground.

(c) Vertical force balance: Find the normal force from the ground, N_g.

Name: ____________________ Date: ____________________ Period: ____________________

CLASSROOM CHALLENGE: THE BOOM CRANE

At the front of the room is the physical apparatus modeled in the diagram below. A vertical post of length L_1 and negligible mass is attached to the floor at point B. A uniform horizontal boom of length L_2 and **unknown mass** M extends to the left from point A. A 50 g mass (m) hangs from the left end. The system is held in static equilibrium by a cable anchored to the floor at angle θ. The tension in the cable is given as $T = 3.0$ N.



(a) Free-Body Diagram: In the space below, draw an extended free-body diagram showing all external forces acting on the L-shaped boom-post assembly. Draw the forces at their correct points of application.

(b) Rotational Equilibrium: Write a fully symbolic equation for the net torque about a point of your choosing. Set your equation equal to zero. *(Hint: Pay attention to the lever arm of the tension force.)*

(c) Calculate the Unknown Mass M: Measure the necessary lengths and angle from the physical setup at the front of the room. Record your measurements below, then use your equation to calculate the mass M of the boom. *(Careful with units: your final mass should be in kg!)*

$L_1 =$ ________ **m** $L_2 =$ ________ **m** $\theta =$ ________ °

(d) Base Support Forces: Calculate the horizontal and vertical components of the support force provided by the floor on the post at point B.

Tomorrow: Review day for Torque & Statics. Bring questions — the mid-unit quiz is Day 6.