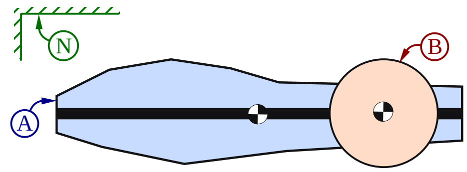
$\vec{\mathrm{M}} = \frac{d\,\vec{\mathrm{H}}}{dt}$: FBD, MG road-maps, and concepts for rotating rigid bodies.

19.1 Concept: Useful equations for 3D mechanics?

$\vec{\mathbf{F}} = m\,\vec{\mathbf{a}}$ is useful for analyzing 3D translational motions of a rigid body. **True/False**

$\vec{\mathrm{M}} = \mathrm{I}\,\vec{\boldsymbol{\alpha}}$ is useful for analyzing 3D rotational motions of a rigid body. **True/False**

19.2 Concept: Rotational motion? (Draw free-body diagrams.)



The figure to the right shows a rigid body B connected to a rigid body A with a **torque/revolute motor** (not shown).

Initially, A and B are **at rest** (stationary) in deep empty space in a Newtonian (inertial) reference frame N.

- It is possible for the torque motor to rotate A in N. **True/False**
- It is possible for the torque motor to rotate B in N. **True/False**
- **†Optional:** Suppose revolute motor's axis of rotation is initially parallel to a vector $\boldsymbol{\lambda}$ fixed in N. Can the motor cause this axis to point in another direction (i.e., so that at some later time the revolute axis is not parallel to $\boldsymbol{\lambda}$)? **Yes/No**. (Hint: See Homework 15.13.)
  Explain: B or A must have a non-zero ______ in a direction associated with $\boldsymbol{\lambda}$.

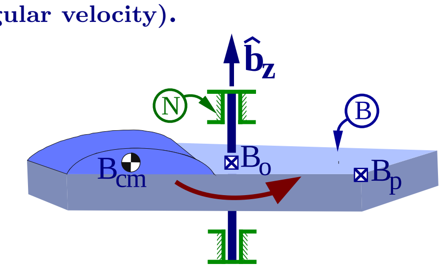
19.3 Concept: When are both $\vec{\mathbf{F}}^S = \vec{0}$ and $\vec{\mathrm{M}}^{S/P} = \vec{0}$ valid? (Draw free-body diagrams.)

Consider a system S on Earth (a Newtonian reference frame) and the quantities $\vec{\mathbf{F}}^S$ (the resultant of all forces on S) and $\vec{\mathrm{M}}^{S/P}$ (the moment of all forces on S about an arbitrary point P).

For each situation below, determine whether **both** $\boxed{\vec{\mathbf{F}}^S = \vec{0}}$ and $\boxed{\vec{\mathrm{M}}^{S/P} = \vec{0}}$ (P is **any** point) apply.	
S is a baseball (particle) dropped from the roof of a two-story building (small air-resistance).	**Yes/No**
S is a baseball (particle) falling at terminal velocity.	**Yes/No**
S is a set of baseballs (particles) falling at terminal velocity.	**Yes/No**
S is a car (rigid body) parked on a hill.	**Yes/No**
S is a car (rigid body) whose every point moves on a straight line at constant speed.	**Yes/No**
S is a car moving on a straight line whose speed changes from 0 to 30 mph in 5 sec.	**Yes/No**
S is a car moving on a circular curve at constant speed.	**Yes/No**
S is a heavy (massive) spring between a wall and a vibrating object (S is just the spring).	**Yes/No**
S is a light (massless) spring between a wall and vibrating object (S is just the spring).	**Yes/No**
S is symmetric rigid windmill blades (with fixed center) spinning with constant angular speed.	**Yes/No**
S is symmetric rigid windmill blades (with fixed center) spinning with varying angular speed.	**Yes/No**

... the whole burden of philosophy seems to consist in this, from the phenomena of motions to investigate the forces of nature, and from the forces to demonstrate the other phenomena. -Isaac Newton, *Principia Philosophiae* (1686)

19.4 Proof of Euler's special 2D rigid body formula (simple angular velocity).



Consider an oddly-shaped rigid body B supported by two rusty (friction-filled) bearings so B spins with a simple angular velocity ${}^N\vec{\boldsymbol{\omega}}^B = \omega_z\,\widehat{\mathbf{b}}_\mathrm{z}$ in a Newtonian reference frame N, where $\widehat{\mathbf{b}}_\mathrm{z}$ is **fixed** in both B and N, parallel to the bearings' axes, and directed vertically upward (opposite gravity). Point B_o of B is at the midpoint between the bearings (along B's axis of rotation in N).

Denoting $\vec{\mathrm{M}}^{B/B_p}$ as the moment of all forces on B about B_p (a point **fixed** on B), and starting with