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

19.1 ♣ Concept: Useful equations for 3D mechanics?

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

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

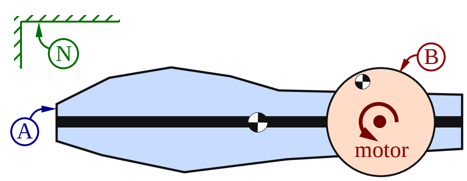
19.2 ♣ Concept: When are both $\vec{F}^S = \vec{0}$ and $\vec{M}^{S/P} = \vec{0}$ valid?

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

For each situation below, determine whether **both** $\boxed{\vec{F}^S = \vec{0}}$ and $\boxed{\vec{M}^{S/P} = \vec{0}}$ (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)

19.3 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**.

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

- The torque motor can rotate A in N **True/False**. Draw A's 3D **FBD**.
- The torque motor can translate A_{cm} in N **True/False**. (A_{cm} is the center of mass of A)
- The torque motor can rotate B in N **True/False**. Draw B's 3D **FBD**.
- The torque motor can translate B_{cm} in N **True/False**. (B_{cm} is the center of mass of B)
- The torque motor can translate S_{cm} in N **True/False**. (S is the system consisting of A and B)
- **†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 15.10.)

  Explain: B or A must have a non-zero ________ in a direction associated with $\boldsymbol{\lambda}$.

19.4 Motor torque for a particle on a spinning slot (MG road-map, FBD, and $\vec{M} = \frac{d\vec{H}}{dt}$).

The following figure shows a rigid body B consisting of a straight track welded to a **horizontal** circular disk that has a simple rotation on Earth (reference frame N). B's mass center B_{cm} is coincident with N_o, a point fixed in N. A particle Q slides with linear viscous damping [equation (21.15)] along the **horizontal** track and a linear-spring [equation (21.7)] connects Q to B_{cm}.