Theme Music: Depeche Mode
Get the Balance Right
Cartoon: Bill Watterson
Calvin & Hobbes
Outline

■ Quiz 8: Circular motion
■ Rotational Kinematics
  – angles
  – angular velocity
■ Rotational Effect of Forces
  – Torque
  – examples
Rotational Effect of Forces: Relevant Factors

- How much force is needed to hold up a weight?
- The distance from the point of rotation clearly makes a difference with farther being more effective, nearer less.
The balance rule

Each force tries to turn the bar in a particular direction. When the forces and distances satisfy the balance rule, it stays balanced.

\[ FL = Wd \]
Example: The Scaffold

- Forces must balance for the CM not to move.
- Torques must balance for the object not to rotate about the CM.

\[ \tau_{\text{clockwise}} = \tau_{\text{counter-clockwise}} \]

\[ F_{\text{up}} = F_{\text{down}} \]

\[ F_{\text{left}} = F_{\text{right}} \]
Does it matter is you choose a different reference point?
Rotational Effect of Forces: Relevant Factors

- Experimentally, the effect is proportional to the distance from the center.
- The angle at which the force is applied clearly makes a difference with perpendicular being most effective, at another angle less.
Rotational Effect of Forces: Torque

- We can figure out a measure of effectiveness by doing a component decomposition of the force vector:
- Only the perpendicular component has a rotational effect.
Definition of Torque

- “Torque” measures the effectiveness of the rotational tendency produced by a force.
- In order for an object not to rotate the torques tending to rotate it opposite ways must balance.

\[ \tau = F_\perp R = FR \sin \theta \]
The Cross Product

- Just as when we defined the dot product in terms of relevant components, we can define a new product, the cross product, which takes 2 vectors and gives back a new vector.

- We take the magnitude of the cross produce = area and the direction of the cross-product = perpendicular to the area spanned by the two vectors (selected by a RH rule).

$\text{area} = AB \sin \theta$
Rotation as a Vector

- Torque tends to produce rotation and the direction of rotation matters.
- Choose the direction associated with a rotation as pointing along the axis of rotation with a right hand rule to choose up or down.
- (RH Rule: Fingers curl around in direction of rotation and thumb points in the direction of the vector.)

\[ \vec{\tau} = \vec{R} \times \vec{F} \]