More than half of you scored $\geq 64/66$ on HW7, which was quite a difficult assignment. Well done!

I know that Chapters 10, 11, 12 have been very difficult to absorb. Look over the HW8 questions, and let me know (email or online form) if there are a couple of questions that you’d like me to sketch out in class on Wednesday.

Only a few people took me up on this offer for today. Maybe everyone else thinks HW8 looks easy?
Problem 5 from HW7

Vertical: \( F_n \cos \theta - \mu F_n \sin \theta - mg = m a_y = 0 \)

Horizontal: \( -F_n \sin \theta + \mu F_n \cos \theta = -m a_x = \frac{m v^2}{R} \)

Solve: \( v^2 = g R \frac{\cos \theta + \mu \sin \theta}{\sin \theta - \mu \cos \theta} \)
This structure is made of 3 identical rods of uniform density. About which axis is rotational inertia *smallest*?
This structure is made of 3 identical rods of uniform density. About which axis is rotational inertia *largest*?
If the rod doesn’t accelerate, what force does the scale read?

(A) 1.0 N  
(B) 5.0 N  
(C) 7.1 N  
(D) 10 N  
(E) 14 N  
(F) 20 N
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Table 12.1

<table>
<thead>
<tr>
<th>Translation</th>
<th>Rotation</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \vec{p} = m\vec{v} )</td>
<td>( \vec{L} = I\vec{\omega} )</td>
<td>( \vec{L} = \vec{r} \times \vec{p} )</td>
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</tbody>
</table>

\[
\Delta \vec{p} = \sum \vec{F}_{\text{ext}} \Delta t \\
\Sigma \vec{F}_{\text{ext}} = \frac{d\vec{p}}{dt} = ma_{cm} \\
K_{cm} = \frac{1}{2} mv^2 \\
\Delta K_{cm} = \left( \sum \vec{F}_{\text{ext}} \right) \cdot \Delta \vec{r}_{cm}
\]

\[
\Delta \vec{L} = \sum \vec{\tau}_{\text{ext}} \Delta t \\
\Sigma \vec{\tau}_{\text{ext}} = \frac{d\vec{L}}{dt} = I\vec{\alpha} \\
K_{\text{rot}} = \frac{1}{2} I\omega^2 \\
\Delta K_{\text{rot}} = \left( \sum \tau_{\text{ext}\theta} \right) \Delta \theta
\]
A bicycle wheel is set spinning as shown. A string is tied to one end of the axle, and someone is holding up the string. Use torque arguments to explain why the wheel slowly precesses horizontally around the string end of the axle when the free end of the axle is released. Why does the precession speed increase as time passes?
A bicycle wheel is set spinning as shown. A string is tied to one end of the axle, and someone is holding up the string. Use torque arguments to explain why the wheel slowly precesses horizontally around the string end of the axle when the free end of the axle is released. Why does the precession speed increase as time passes?

\[
\frac{d\vec{L}}{dt} = \vec{\tau} = \vec{r} \times \vec{F}
\]

So \( \frac{d\vec{L}}{dt} \) points into the page.
What happens (when I hold the axle horizontally and release one end, holding the other end from a string) if the two bicycle wheels are spinning opposite directions, at about the same speed?

(A) Direction of rotation doesn’t matter — the wheels will still stay suspended by one end, and they will still slowly precess

(B) The wheels will still stay suspended by one end, but they won’t precess, because the two wheels’ angular momentum vectors point in opposite directions

(C) The wheels will just dangle from the end of the string, just as they would if they were not spinning, because the net angular momentum is close to zero
People asked about torques in architecture and (closely related) mechanical equilibrium. We will spend a big part of weeks 11–12 on this, but you’ll start to get the flavor of it in next week’s homework. For example:

15. You want to hang a 10 kg sign (shown at right) that advertises your new business. To do this, you attach a 5.0 kg beam of length $\ell$ to a wall at its base by a pivot $P$. You then attach a thin cable to the beam and to the wall in such a way that the cable and beam are perpendicular to each other. The beam makes an angle of $37^\circ$ with the vertical. You hang the sign from the end of the beam to which the cable is attached. (a) What must be the minimum tensile strength of the cable (the amount of tension it can sustain) if it is not to snap? (b) Determine the horizontal and vertical components of the force the pivot exerts on the beam.
A 215 g can of soup is 10.8 cm tall and has a radius of 3.19 cm. 
(a) Calculate its theoretical rotational inertia, assuming it to be a solid cylinder. (b) When it is released from rest at the top of a ramp that is 3.00 m long and makes an angle of 25° with the horizontal, it reaches the bottom in 1.40 s. What is the experimental rotational inertia? (c) Compare the experimental and theoretical rotational inertias and suggest possible sources of the difference.
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One constant-acceleration trick that you may not have seen: if you solve \( x_f = \frac{1}{2} at^2 \) for \( a \) and then plug \( a = \frac{2x_f}{t^2} \) into \( v_f^2 = 2ax_f \), you get (for \( v_i = 0, x_i = 0, a = \text{constant} \)):

\[
v_f^2 = 2 \left( \frac{2x_f}{t^2} \right) x_f = \frac{4x_f^2}{t^2}
\]

Now use energy conservation to relate \( I \) to \( v_f^2 \) …
A square clock of inertia $M = 5.0 \text{ kg}$ is hung on a nail driven in a wall, as shown at right. The length of each side of the square is $\ell = 20 \text{ cm}$, the thickness is $w = 10 \text{ cm}$, and the clock is a distance $d = 0.1 \text{ cm}$ from the wall at the top, where it hangs on the nail. Assume that the surface of the wall is very smooth and that the center of mass of the clock corresponds to its geometric center. What is the magnitude of the normal force exerted by the wall on the clock? Make simplifying approximations — any answer within 10% of the correct answer gets full credit.
For Wednesday

- Read the rest of Chapter 13
- Tell me if there are other HW8 problems you want me to outline in class
- We’ll talk more about gravity
- Don’t be too worried if you’re confused by some of the details of Chapter 13. The main things I want you to remember are

\[ F = \frac{GM_1 m_2}{r^2} \]

and which direction \( \vec{F} \) points. The discussion of gravitational potential energy is also important.

- The calculus derivations are mainly there for your liberal-arts education: just remember the results for inside vs. outside a spherical shell of uniform density.