Problem 1 (46 points). [NOTE: Parts (a) and (b) of this problem are independent of each other. You can do part (b) without first having done part (a).]

A uniform rod of mass $m$ and length $L$ is attached to the ceiling by a pivot and by a cable. Attached to the rod at the end opposite the pivot is a small ball of the same mass $m$. The rod makes an angle $\theta$ with the ceiling, and the cable makes a right angle with the rod.

(a) **Find the $x$ and $y$ components of the force exerted on the rod by the pivot.** Use the $x$ and $y$ coordinates shown in the figure above. Your answers should involve no quantities other than $m$, $L$, $g$, and $\theta$. (They may or may not involve all of these quantities. You will lose points if you substitute a numerical value for $g$.) For full credit, **show your work, simplify your answers, and draw a box around your final answers.**
Problem 1 (continued)

(b) You use a pair of scissors to cut the cable, and the rod (with ball attached) begins to swing around the pivot. **Find the magnitude of the angular acceleration of the rod and ball just after the cable is cut.** Your answer should involve no quantities other than $m$, $L$, $g$, and $\theta$. (It may or may not involve all of these quantities. You will lose points if you substitute a numerical value for $g$.) For full credit, show your work, simplify your answer, and draw a box around your final answer.

Possibly useful information:

- Moment of inertia of a rod of mass $m$ and length $L$ around its center: $I = \frac{1}{12}mL^2$
- Moment of inertia of a rod of mass $m$ and length $L$ around one end: $I = \frac{1}{3}mL^2$
- Moment of inertia of a collection of masses $m_i$: $I = \sum_i m_i r_i^2$
- Number of lakes in the Great Lakes: five
Problem 2 (30 points) The Galactic Empire is trying to disrupt the activities of the Rebel Alliance on the ice planet Hoth, which has mass $m_H$ and radius $R$ and rotates with angular speed $\omega_0$. To do this, the Empire causes two identical asteroids, each of mass $m_A$, to impact on opposite sides of Hoth in the plane of Hoth’s equator: that is, in the $xy$-plane, with the origin at the center of the planet. Both asteroids impact the surface of Hoth at the same time, each moving at speed $v$ when the hit the surface.

Asteroid 1 is moving in the $-y$ direction when it impacts the equator of Hoth at $x = +R/2$, and asteroid 2 is moving in the $+y$ direction when it impacts the equator of Hoth at $x = -R/2$. Both asteroids stick to the planet after the collision. The moment of inertia of Hoth for an axis through its center is $I_H$.

Find the angular speed of Hoth after the two asteroids collide with and stick to Hoth. Your answer should involve no quantities other than $m_A$, $m_H$, $R$, $v$, $\omega_0$, $I_H$, and $G$. ([It may or may not involve all of these quantities. You will lose points if you substitute a numerical value for $G$.) For full credit, show your work, simplify your answer, and draw a box around your final answer.

View looking down on Hoth from above its north pole
Multiple-choice questions (24 points). For each of these three questions, mark a clear “X” in the box next to the correct answer.

1. A steel lift column in a service station is a solid cylinder 4.0 m long and 0.20 m in diameter. Young’s modulus for this steel is $20 \times 10^{10}$ N/m$^2$. By what distance does the column compress when a 5000-kg truck is on it?

□ (a) $3.2 \times 10^{-6}$ m
□ (b) $7.8 \times 10^{-6}$ m
□ (c) $8.0 \times 10^{-7}$ m
□ (d) $3.1 \times 10^{-4}$ m
□ (e) $4.7 \times 10^{-7}$ m

2. A wheel has a radius of 0.40 m and is mounted on frictionless bearings. A block is suspended from a rope that is wound on the wheel and attached to it (see figure). The wheel is released from rest and the block descends 1.5 m in 2.00 s without any slipping of the rope. The tension in the rope during the descent of the block is 20 N. What is the moment of inertia of the wheel?

□ (a) 4.1 kg · m$^2$
□ (b) 3.9 kg · m$^2$
□ (c) 3.5 kg · m$^2$
□ (d) 4.3 kg · m$^2$
□ (e) 3.7 kg · m$^2$

3. The moons of Mars, Phobos (Fear) and Deimos (Terror), are very close to the planet compared to Earth's Moon. Their orbital radii are 9,378 km and 23,459 km respectively. What is the ratio of the orbital speed of Phobos to that of Deimos?

□ (a) 1.582
□ (b) 2.858
□ (c) 0.2528
□ (d) 0.3998
□ (e) 3.956