Your name: _____

Please show your work, write neatly, and put a box or circle around each of your answers.
Assume Earth's gravitational acceleration ($g = 9.8$ m/s^2) unless otherwise specified.
There are 6 problems. Some are quick and some are a bit more involved.
Remember to include units where appropriate!
(Yes, there are 110 possible points. That's intentional.)

1. **Stress/Strain** (15 total points)

   Four steel legs, each of circular cross section with diameter 10 cm and length 1.0 m, support a large steel table of mass $m = 3 \times 10^4$ kg. The pressure on each beam is equal.

   (a) (5 points) What is the pressure on each leg of the table?

   (b) (10 points) How far does each leg of the table compress?

2. **Fluid Mechanics** (15 total points)

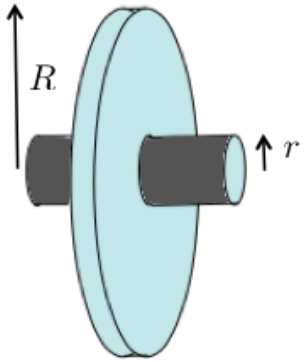
A slab of ice 2.0 m per side and 1.0 m thick floats on a pure freshwater lake.

(a) (5 points) How much thickness of the ice slab is exposed above the lake's surface?

(b) (5 points) A 75 kg woman gently steps onto the ice slab and stands on it, pushing the ice down into the water a bit. How much thickness of the ice slab is exposed above the lake's surface in this case?

(c) (5 points) If the woman quickly jumps to accelerate upwards at 3.0 m/s^2, does the ice slab bob below the surface of the water? Why or why not?

3. **Angular Kinematics** (30 total points)



A gyroscope is built from a solid uniform disk of radius $R = 4$ cm and mass M =500 g, centered on an axle of radius $r = 0.4$ cm and mass m=100 g. The system can spin around the center of the axle.

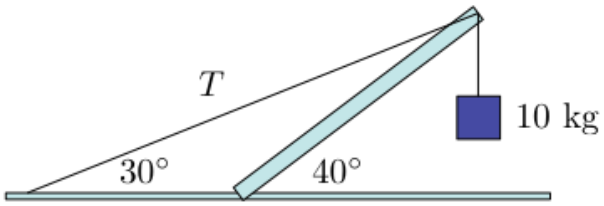
(a) (5 points) What is the total rotational inertia $I_{\text{tot}} = I_{\text{disk}} + I_{\text{axle}}$ of the gyroscope when rotated around the axis centered on the axle?

(b) (5 points) A massless string is wrapped around the axle and pulled with a constant tension of $T = 0.1$ N. What is the angular acceleration α of the gyroscope in units of rad/s^2?

(c) (10 points) If the gyroscope is at rest, then the string is pulled for 7 s, how many revolutions does the gyroscope make while the string is being pulled?

(d) (10 points) What is the gyroscope's final angular velocity ω after the string is pulled, in units of rad/s?

4. **Static Equilibrium** (20 total points)



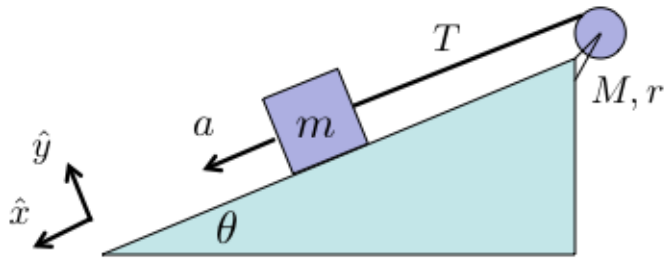
A small crane supports a mass of 10 kg as shown above. The crane boom is 3 m long, has a uniformly distributed mass of 5 kg, and is hinged to the ground at its base, and it is attached to the ground behind it with a rope of tension T.

(a) (10 points) What is the tension T (in Newtons) such that this crane is in static equilibrium?

(b) (5 points) What is the magnitude of the force that the ground exerts on the crane boom (in Newtons)?

(c) (5 points) What is the angle of the force that the ground exerts on the crane boom, in degrees from the positive horizontal direction?

5. **Rotational Motion on a Frictionless Ramp** (20 total points)

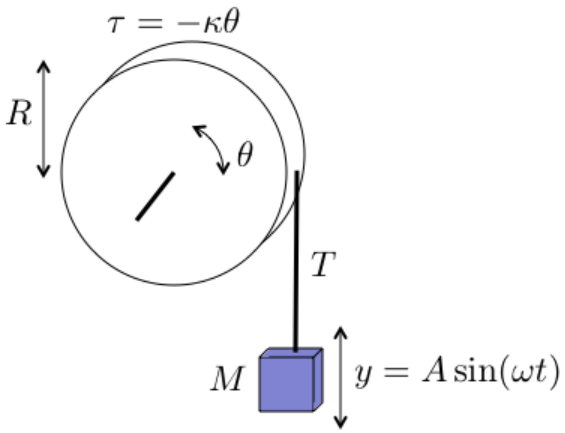


A mass m=5.0 kg is accelerating down a *frictionless* ramp of angle $\theta = 30°$ with acceleration a=1.0 m/s^2. It is attached to a *massless* string which is wound around a cylinder of mass M and radius r=20 cm. The string has tension T that is parallel to the surface of the ramp, and it turns the cylinder as the mass is sliding down the ramp.

(a) (10 points) What is the tension T in the string?

(b) (10 points) What is the mass M of the cylinder?

6. **Torsional Spring** (10 total points)



A very light (effectively massless) cylinder of radius R=50 cm turns on its axis, and is attached to a spring that exterts a torque τ on it that depends on the rotation of the cylinder θ, via the equation $\tau = -\kappa\theta$ where κ=5 N·m.

(a) (5 points) A mass M=50 g is hung from the side of the cylinder with a *massless* string of tension T, and gently released so the system achieves static equilibrium. How far did the wheel turn?

(b) (5 points) What is the tension T in the string (in Newtons) after the system is in static equilibrium?