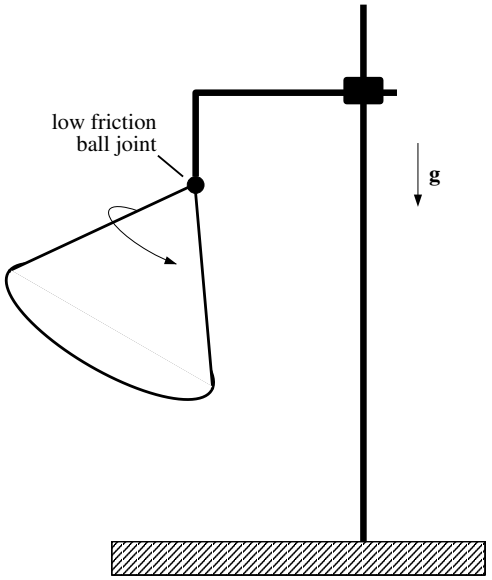
Unless stated otherwise, circle the letter of the single best answer. Each answer is worth 1 point.

Physical Constants:

$g = 9.80\ \mathrm{m/s^2}$
$G = 6.67 \times 10^{-11} \mathrm{m^3 \cdot kg^{-1} \cdot s^{-2}}$

1. (Circle two answers!) A gyroscope consists of a metal cone supported by a low friction ball joint at its apex. The gyroscope is set spinning in the direction shown.



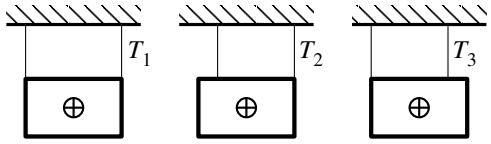
The torque of gravity about the ball joint:

A. points out of this page
B. points into this page

The precession of the gyroscope as seen from above is

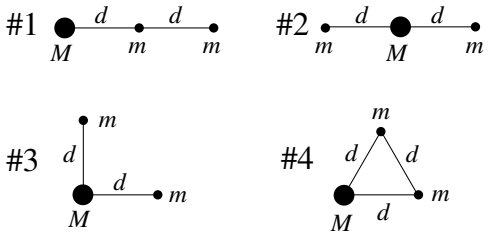
C. clockwise
D. counter-clockwise

2. A picture is to be hung from the ceiling by means of two wires. Three situations are considered (see below). Rank the right wire tension in the three situations from least to greatest. The center of mass of the picture (labeled below $\oplus$) is in the center of the picture.



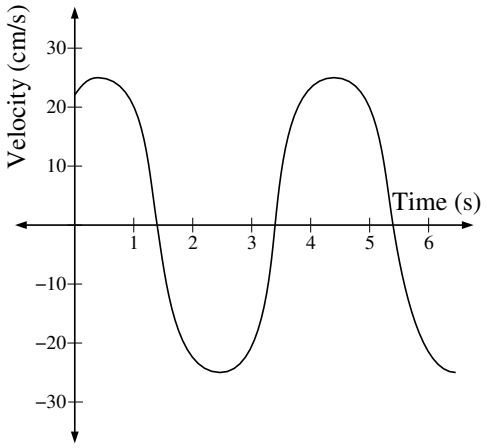
A. $T_1 < T_2 < T_3$
B. $T_2 < T_1 < T_3$
C. $T_3 < T_1 < T_2$
D. None of the above

3. A heavy object of mass M and two lighter objects of mass m are spaced by a distance d in four different arrangements. Order the potential energy of the arrangements from least to most. (Note: $-100 < -10$; U_1 is the total potential energy in situation #1, etc.)



A. $U_4 < U_3 < U_2 < U_1$
B. $U_1 < U_2 < U_3 < U_4$
C. $U_2 < U_1 < U_3 < U_4$
D. $U_3 < U_4 < U_2 < U_1$

4. The velocity of a particle undergoing simple harmonic motion as a function of time is displayed below. We seek the *position*, x, of the particle at the time $t = 2$ s. The maximum x (i.e., the amplitude) is denoted by A; the equilibrium location is $x = 0$.



A. the particle's x position is between 0 and A, moving away from equilibrium.

B. the particle's x position is between A and 0, moving back towards equilibrium.

C. the particle's x position is between 0 and $-A$, moving away from equilibrium.

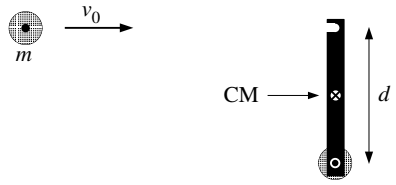
D. the particle's x position is between $-A$ and 0, moving back towards equilibrium.

The following questions are worth 5 pts each

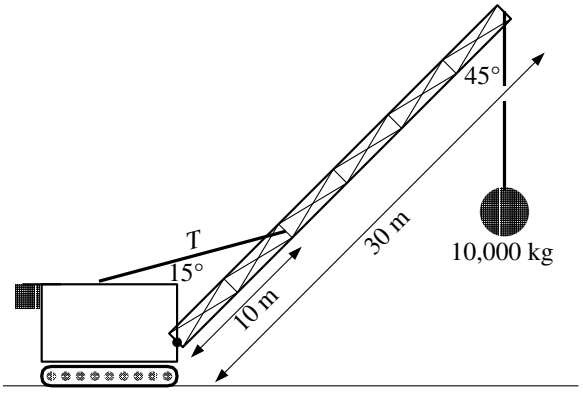
5. Two identical pucks, each of mass m, float frictionlessly on a horizontal plane. A "catcher" is designed catch and hold a moving puck. *When so held*, the pucks are distance d apart, the center of mass is midway between the two pucks, the system has an about-CM moment of inertia I, and a total mass M. Currently the system (minus one puck) is stationary and the missing puck is approaching the catcher with a velocity v_0 as shown below. The catcher will grab and hold the moving puck when the collision occurs.

   A. What exactly will be conserved in the collision (e.g., energy, momentum, angular momentum, mass, ...)?

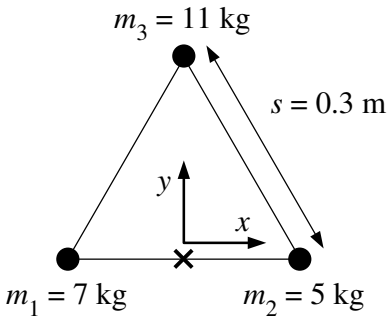
   B. Find the CM velocity and the angular velocity of the combined system following the "catch".



6. The derrick of a crane has a mass of 3,000 kg distributed uniformly along its 30 m length. The derrick is inclined at 45° and supports a 10,000 kg ball at its far end. The derrick is supported by the tension T in a cable that is inclined at 15° and connects to the derrick 10 m from its end. Find the cable tension T. One might worry that the crane is in danger of tipping over. What condition must be met to be sure the crane will remain upright?



7. Masses m_1, m_2, and m_3 are placed at the corners of an equilateral triangle. Find the total force on a 2 kg mass placed at the spot marked with an X: the midpoint of the horizontal segment. Forces are vectors so you'll want to report x and y components. Draw a diagram showing the direction of each force acting on the 2 kg mass.



8. A block sliding frictionlessly on a horizontal surface is attached to the wall with a 500 N/m spring. The block executes SHM about its equilibrium position with a period of 0.4 seconds and an amplitude of 10 cm. As the block slides through equilibrium, a 0.5 kg putty wad is dropped vertically onto the block. If the putty sticks to the block, find the new amplitude of the motion.