# 2.003 Engineering Dynamics
Problem Set 8

This is a sample quiz. It was handed out as a study aid in advance of the second quiz in the course in the fall of 2011. It is an actual quiz from a prior year. There were no concept questions. Students had 90 minutes to work the quiz and were allowed two pages of notes, both sides of the page. No textbooks allowed.

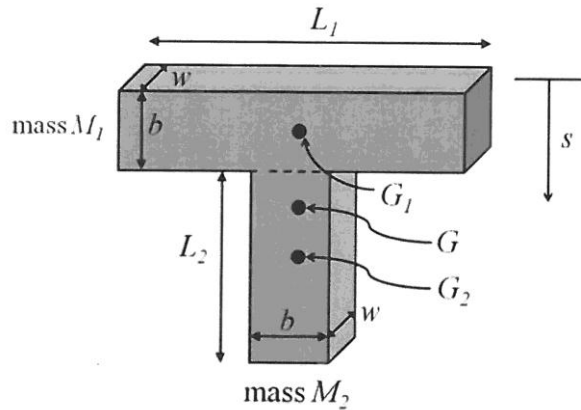There is an important appendix, given with the solution to problem 4. Don¨t miss it.

Problem 1:

A slender rod of mass M and length, L, moves around a circular track under the influence of gravity. The small rollers at the ends of the rod are confined to the circular track and roll without friction. Neglect the mass of the rollers. The radius of the track is R and $L = \sqrt{3}R$. Find an equation of motion of the rod as a function of the coordinate, θ, as shown in the figure. The frame $G_{x''y''z''}$ is fixed to the center of mass of the rod.
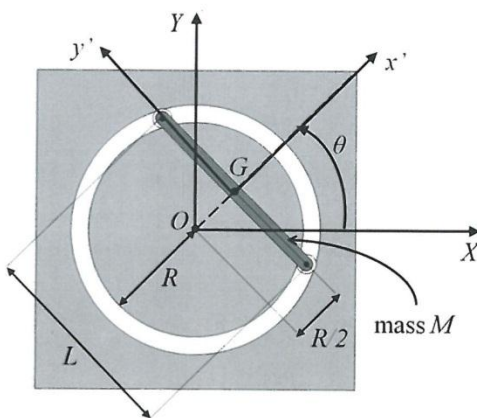
Problem 2:

A T-shaped object is made from two rectangular solid blocks of uniform density. Both blocks have thickness „w" and width „b". The horizontal part of the "T" has length L_1 and mass M_1. The vertical part has length L_2 and mass M_2. G_1 and G_2 are the centers of mass of each block and are located at the geometric centers of each block.

a). Find the location of the center of mass of the combined object, which lies somewhere on the vertical line which passes through G_1 and G_2. Express it as a distance „s" measured from the top of the "T", as shown in the figure.

b). On a sketch of the combined object, draw the three principal axes, with their origin at „G" the center of mass of the combined object. Label them as an xyz coordinate system. It is most important that you show the orientation of the axes with respect to the object.

Problem 3:

The T-shaped object described in the previous problem is rotated at constant speed, ω_z, about the z-axis shown in the figure below. The axis passes through, G_2, the center of mass of the vertical block and is perpendicular to the plane of the „T".
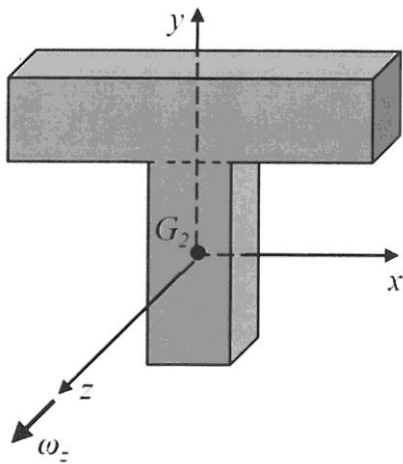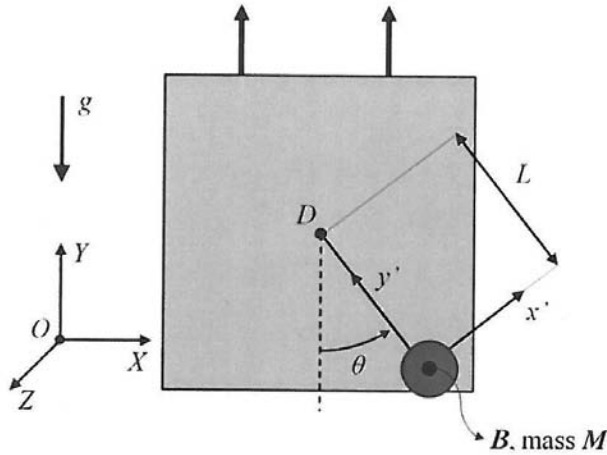
a). Compute the force which must be applied to the axle to keep it from moving as the object rotates.

b). The presence of this force is evidence that the body has what type of imbalance? A. Static, B. Dynamic, C. Both.

Problem 4:

A simple pendulum made of a point mass, M, suspended in an elevator from point D. O_{xyz} is a fixed inertial reference frame with unit vectors $\hat{I}, \hat{J}, \hat{K}$. The $B_{x'y'z''}$ frame is attached to the pendulum, as shown, with unit vectors $\hat{i}, \hat{j}, \hat{k}$. It is strongly suggested that you use these reference frames and unit vectors in solving the problem below.

The elevator has velocity $\dot{Y}$ and acceleration $\ddot{Y}$. Their values are given and therefore „Y" does not have to be considered an independent degree of freedom, because it is constrained to fixed values. The elevator is also not allowed to move in the X or Z directions. This is a planar motion problem, requiring one independent coordinate, θ, as shown in the figure to the left.

One method that can be used to obtain the equation of motion of this pendulum is to apply the physical law relating angular momentum to torque, about a moving point, „A", as given below. „G" in the equation is the center of mass of the rigid body.

$$\sum_i \vec{\tau}_{i/A} = \left(\frac{d\vec{H}_{/A}}{dt} \right)_{O_{xyz}} + \vec{v}_{A/O} \times \vec{P}_{G/O} \qquad (1)$$

Equation (1) is true for all rigid bodies. A very useful variation for finding $\vec{H}_{/A}$ is given in Equation (2) below, which is also generally true for rigid bodies.

$$\vec{H}_{/A} = \vec{H}_{/G} + \vec{r}_{G/A} \times \vec{P}_{G/O} \qquad (2)$$

 a) In a sketch define the rigid body in this problem. Mark clearly in your sketch which points correspond to the points „A" and „G", which are referred to in the equations above.

 b) Find for this particular problem the vector expressions for
 $\vec{v}_{A/O}, \vec{P}_{G/O}, \sum_i \vec{\tau}_{i/A}, \text{ and } \vec{H}_{/A}.$

 c) Find the equation of motion. This takes time so save it to the end of the exam.

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