

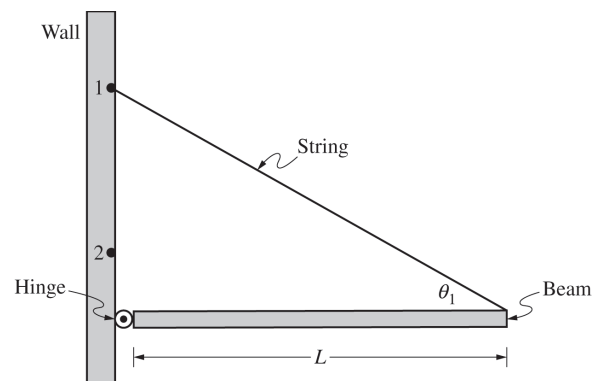
Begin your response to **QUESTION 3** on this page.

Figure 1

3. (12 points, suggested time 25 minutes)

The left end of a uniform beam of mass M and length L is attached to a wall by a hinge, as shown in Figure 1. One end of a string with negligible mass is attached to the right end of the beam. The other end of the string is attached to the wall above the hinge at Point 1. The beam remains horizontal. The hinge exerts a force on the beam of magnitude F_H , and the angle between the beam and the string is $\theta = \theta_1$.

- (a) The following rectangle represents the beam in Figure 1. On the rectangle, **draw** and **label** the forces (not components) exerted on the beam. Draw each force as a distinct arrow starting on, and pointing away from, the point at which the force is exerted.



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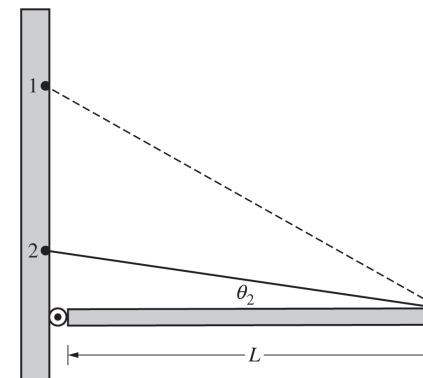
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Figure 2

- (b) The string is then attached lower on the wall, at Point 2, and the beam remains horizontal, as shown in Figure 2. The angle between the beam and the string is $\theta = \theta_2$. The dashed line represents the string shown in Figure 1.

The magnitude of the tension in the string shown in Figure 1 is F_{T1} . The magnitude of the tension in the string shown in Figure 2 is F_{T2} . **Indicate** which of the following correctly compares F_{T2} with F_{T1} .

_____ $F_{T2} > F_{T1}$ _____ $F_{T2} < F_{T1}$ _____ $F_{T2} = F_{T1}$

Briefly **justify** your answer, using qualitative reasoning beyond referencing equations.

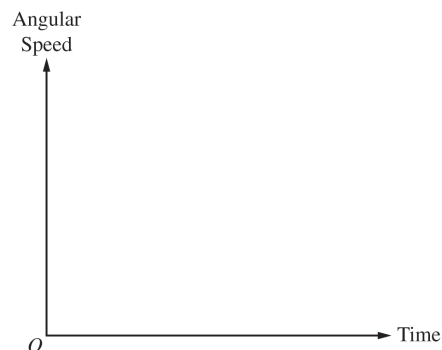
- (c) Starting with Newton's second law in rotational form, **derive** an expression for the magnitude of the tension in the string. Express your answer in terms of M , θ , and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference book.

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Continue your response to **QUESTION 3** on this page.

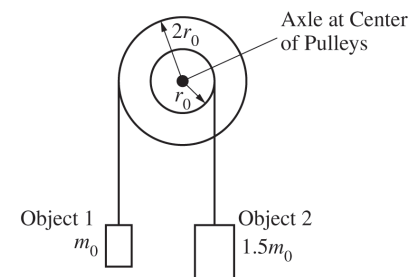
(d) Is your derived equation in part (c) consistent with your justification in part (b) ? **Explain** your reasoning.

(e) The string is cut, and the beam begins to rotate about the hinge with negligible friction. On the following axes, **sketch** the angular speed of the beam as a function of time for the time interval while the beam falls but before the beam becomes vertical.



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Begin your response to **QUESTION 5** on this page.



5. (7 points, suggested time 13 minutes)

Two pulleys with different radii are attached to each other so that they rotate together about a horizontal axle through their common center. There is negligible friction in the axle. Object 1 hangs from a light string wrapped around the larger pulley, while object 2 hangs from another light string wrapped around the smaller pulley, as shown in the figure above.

m_0 is the mass of object 1.

$1.5m_0$ is the mass of object 2.

r_0 is the radius of the smaller pulley.

$2r_0$ is the radius of the larger pulley.

(a) At time $t = 0$, the pulleys are released from rest and the objects begin to accelerate.

i. Derive an expression for the magnitude of the net torque exerted on the objects-pulleys system about the axle after the pulleys are released. Express your answer in terms of m_0 , r_0 , and physical constants, as appropriate.

ii. Object 1 accelerates downward after the pulleys are released. Briefly explain why.

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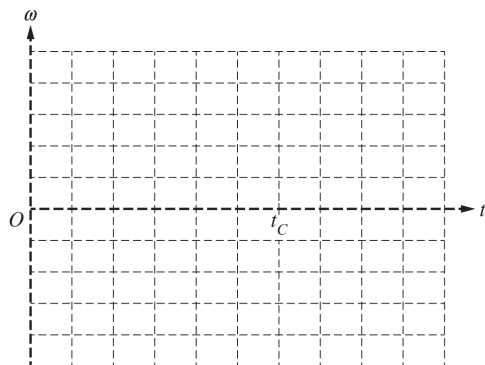
Write your responses to questions 5 and 6 on this page.

- (b) At a later time $t = t_C$, the string of object 1 is cut while the objects are still moving and the pulley is still rotating. Immediately after the string is cut, how do the directions of the angular velocity and angular acceleration of the pulley compare to each other?

___ Same direction ___ Opposite directions

Briefly explain your reasoning.

- (c) On the axes below, sketch a graph of the angular velocity ω of the system consisting of the two pulleys as a function of time t . Include the entire time interval shown. The pulleys are released at $t = 0$, and the string is cut at $t = t_C$.



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END OF EXAM