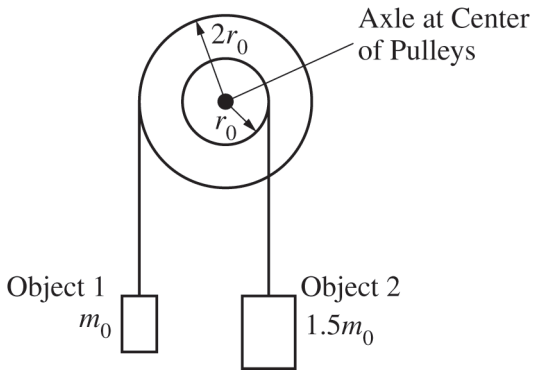
Begin your response to **QUESTION 5** on this page.



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.

GO ON TO THE NEXT PAGE.

Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

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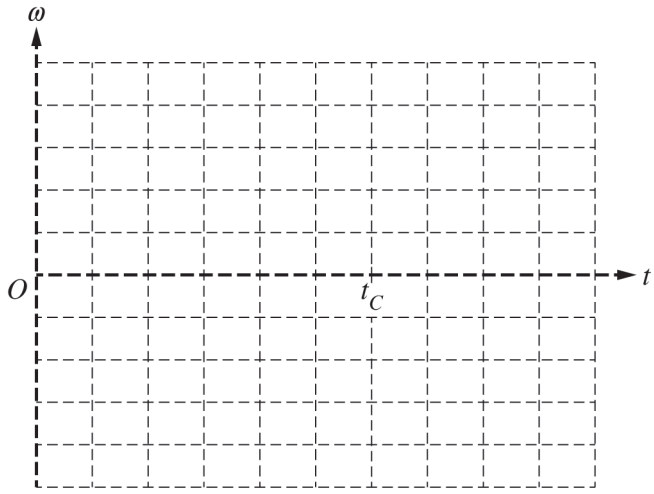
Continue your response to **QUESTION 5** on this page.

(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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Question 5: Short Answer — 7 points

(a) i. For correct expressions for the torques from the weight of each object — **1 point**

The torques are $m_0 g(2r_0)$ for object 1 and $(1.5m_0 g)r_0$ for object 2

For indicating that the two torques are exerted in opposite directions — **1 point**

$\tau_{\text{net}} = m_0 g(2r_0) - (1.5m_0 g)r_0$

For the derivation of a correct answer of $0.5m_0 g r_0$ — **1 point**

Example response for part (a)(i)

$\tau_{\text{net}} = \tau_1 - \tau_2$
$\tau_{\text{net}} = m_0 g(2r_0) - (1.5m_0 g)r_0$
$\tau_{\text{net}} = 0.5m_0 g r_0$

ii. For an explanation that object 1 exerts a larger torque than object 2 — **1 point**

Example response for part (a)(ii)

Object 1 is twice as far from the axle as object 2, while object 2 has only 1.5 times the weight of object 1. So, object 1 exerts a larger torque.

Total for part (a) 4 points

(b) Correct answer: "Opposite directions"

Scoring note: If the wrong answer is selected, the response is not graded.

For a correct answer and a correct explanation — **1 point**

Example response for part (b)

The objects exerted torques in opposite directions, with object 1 exerting a larger torque, so object 1 determines the net torque direction. With the torque from object 1 removed, the net torque and angular acceleration switch direction (becoming clockwise) to the torque from object 2. The angular velocity does not change direction immediately and is still counterclockwise.

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(c) For a linear graph between 0 and t_C, with an initial angular velocity of zero and nonzero slope **1 point**

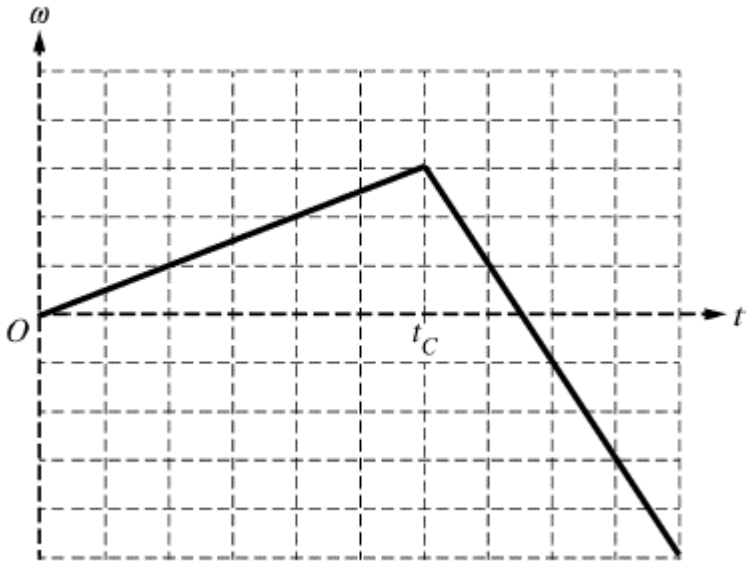
Scoring note: The slope can be positive or negative.

For a change in the sign of the slope at $t = t_C$ **1 point**

AND

no discontinuity.

Example response for part (c)



Total for part (c) 2 points

Total for question 5 7 points

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