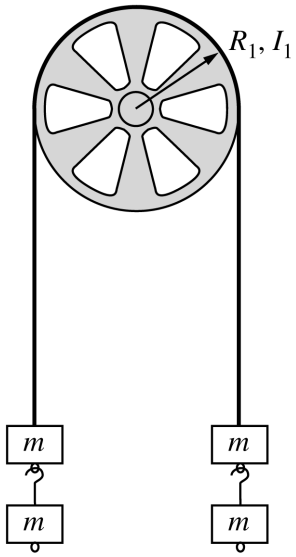
2000 AP® PHYSICS C FREE-RESPONSE QUESTIONS



Mech 3.

A pulley of radius R_1 and rotational inertia I_1 is mounted on an axle with negligible friction. A light cord passing over the pulley has two blocks of mass m attached to either end, as shown above. Assume that the cord does not slip on the pulley. Determine the answers to parts (a) and (b) in terms of m, R_1, I_1, and fundamental constants.

(a) Determine the tension T in the cord.

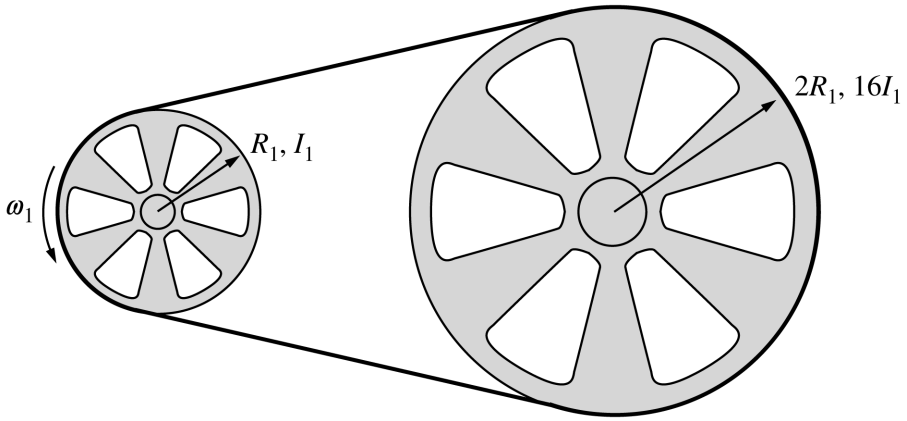
(b) One block is now removed from the right and hung on the left. When the system is released from rest, the three blocks on the left accelerate downward with an acceleration $\frac{g}{3}$. Determine the following.

i. The tension T_3 in the section of cord supporting the three blocks on the left

ii. The tension T_1 in the section of cord supporting the single block on the right

iii. The rotational inertia I_1 of the pulley

GO ON TO THE NEXT PAGE.



(c) The blocks are now removed and the cord is tied into a loop, which is passed around the original pulley and a second pulley of radius $2R_1$ and rotational inertia $16I_1$. The axis of the original pulley is attached to a motor that rotates it at angular speed ω_1, which in turn causes the larger pulley to rotate. The loop does not slip on the pulleys. Determine the following in terms of I_1, R_1, and ω_1.

i. The angular speed ω_2 of the larger pulley

ii. The angular momentum L_2 of the larger pulley

iii. The total kinetic energy of the system

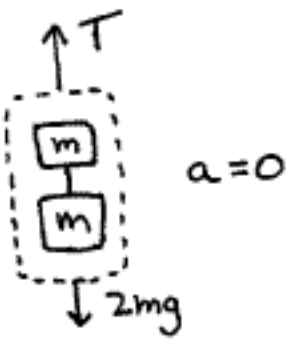
S T O P

END OF SECTION II, MECHANICS

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON SECTION II, MECHANICS, ONLY. DO NOT TURN TO ANY OTHER TEST MATERIALS.

Mech. 3 (15 points)

(a) 2 points



For a correct free-body diagram OR recognition that $a = 0$ OR correct use of Newton's second law — 1 point

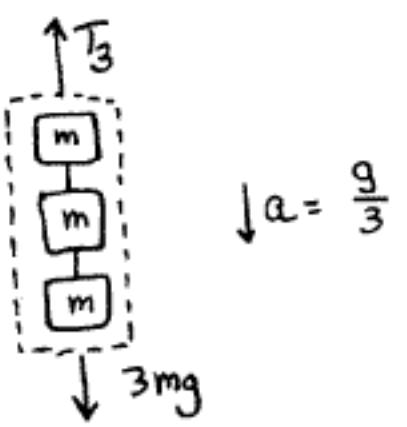
$\Sigma F = ma$
$T - 2mg = 0$

For the correct answer — 1 point
$T = 2mg$

Full credit was also awarded for writing the correct answer with no other work shown.

(b)

i. 2 points



$\Sigma F = ma$
For correct substitutions into Newton's second law — 1 point

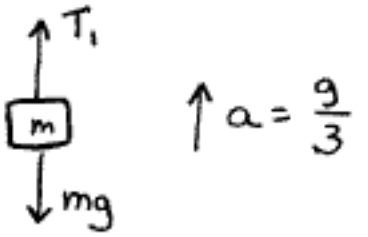
$3mg - T_3 = 3m\left(\frac{g}{3}\right)$

For a correct solution for T_3 — 1 point
$T_3 = 2mg$

Mech. 3 (continued)

(b) (continued)

ii. 2 points



$\Sigma F = ma$
For correct substitutions into Newton's second law — 1 point

$T_1 - mg = m\left(\frac{g}{3}\right)$
For a correct solution for T_1 — 1 point

$T_1 = \frac{4}{3}mg$

iii. 4 points

For $\tau = I_1\alpha$ — 1 point
For $\alpha = \frac{a}{R_1} = \frac{g}{3R_1}$ — 1 point
For $\tau = (T_3 - T_1)R_1$ — 1 point
For correct substitutions into $\tau = I_1\alpha$ and solution for I_1 — 1 point

$\left(2mg - \frac{4}{3}mg\right)R_1 = I_1\left(\frac{g}{3R_1}\right)$

$I_1 = 2mR_1^2$

Alternate Solution — *(alternate points)*
Use conservation of energy, $\Delta E = \Delta K + \Delta U = 0$
For $\Delta K = -\Delta U$ — *(1 point)*
For $\Delta K = \frac{1}{2}mv^2 + \frac{1}{2}(3m)v^2 + \frac{1}{2}I_1\omega^2$, where $\omega = \frac{v}{R_1}$ — *(1 point)*
For $\Delta U = mgh - 3mgh = -2mgh$, where $h = \frac{v^2}{2a} = \frac{3v^2}{2g}$ — *(1 point)*
For correct substitutions and solution for I_1 — *(1 point)*

$I_1 = 2mR_1^2$

Mech. 3 (continued)

(c)

i. 2 points

For recognition that the speed of the cord or the tangential speed of the pulleys is the same for both pulleys — 1 point

$\omega_1 R_1 = \omega_2 R_2 = \omega_2(2R_1)$

For the correct answer — 1 point

$\omega_2 = \frac{\omega_1}{2}$

ii. 1 point

For correct substitutions in $L = I\omega$ and correct solution — 1 point

$L_2 = (16I_1)\left(\frac{\omega_1}{2}\right)$

$L_2 = 8I_1\omega_1$

iii. 2 points

For a correct expression for the kinetic energy as the sum of the kinetic energies of the two pulleys — 1 point

$K = \frac{1}{2} I_1\omega_1{}^2 + \frac{1}{2} I_2\omega_2{}^2$

For correct substitutions and solution — 1 point

$K = \frac{1}{2} I_1\omega_1{}^2 + \frac{1}{2} (16I_1)\left(\frac{\omega_1}{2}\right)^2$

$K = \frac{5}{2} I_1\omega_1{}^2$