AP® Physics C: Mechanics
1999 Sample Student Responses

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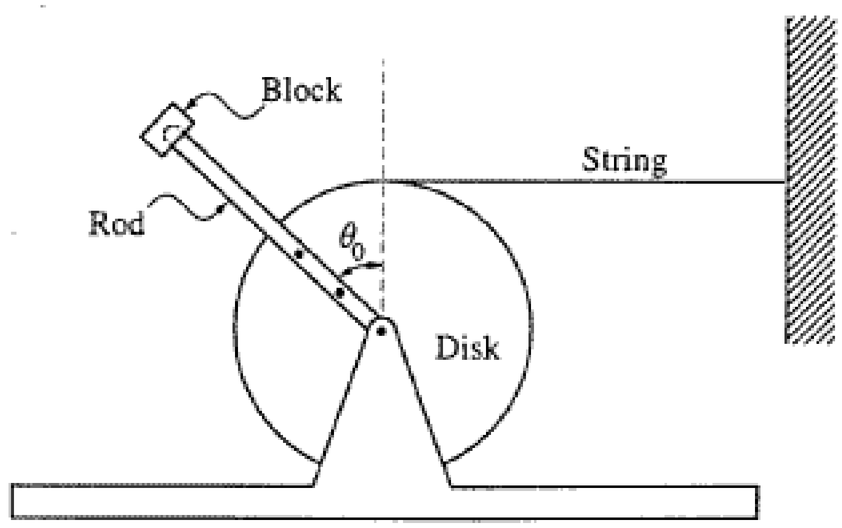

Mech 3. As shown above, a uniform disk is mounted to an axle and is free to rotate without friction. A thin uniform rod is rigidly attached to the disk so that it will rotate with the disk. A block is attached to the end of the rod. Properties of the disk, rod, and block are as follows.

Disk: mass $= 3m$, radius $= R$, moment of inertia about center $I_D = \frac{3}{2}mR^2$

Rod: mass $= m$, length $= 2R$, moment of inertia about one end $I_R = \frac{4}{3}mR^2$

Block: mass $= 2m$

The system is held in equilibrium with the rod at an angle θ_0 to the vertical, as shown above, by a horizontal string of negligible mass with one end attached to the disk and the other to a wall. Express your answers to the following in terms of m, R, θ_0, and g.

(a) Determine the tension in the string.

$\tau =$

$\tau = mgr\sin\theta$ ← Torque of g-field on ~~block~~ rod

$\tau = 2mg(2R)\sin\theta$ on block

$\tau = 5mgr\sin\theta.$

$\tau_{string} = r \times F = -RT$

$\tau_{NET} = 5mgR\sin\theta - rT = 0$

$5mg\sin\theta_0 = T$

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The string is now cut, and the disk-rod-block system is free to rotate.

(b) Determine the following for the instant immediately after the string is cut.

i. The magnitude of the angular acceleration of the disk

$\tau_{net} = 5mgR\sin\theta_0 = I\alpha$

$I = \frac{3}{2}mR^2 + \frac{4}{3}MR^2 + (2m)(2R)^2$

$I = \frac{65mR^2}{6}$

$5mgR\sin\theta_0 = \frac{65}{6}mR^2\alpha$

$\alpha = \frac{6}{13}g\frac{\sin\theta_0}{R}$

ii. The magnitude of the linear acceleration of the mass at the end of the rod

$a = \alpha r = 2R\alpha.$

$a = \frac{12}{13}g\sin\theta_0$

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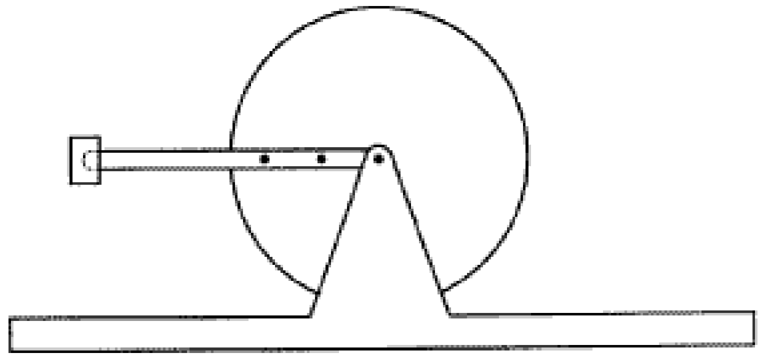

As the disk rotates, the rod passes the horizontal position shown above.

(c) Determine the linear speed of the mass at the end of the rod for the instant the rod is in the horizontal position.

Use Energy. $\Delta U_{grav\,(disk)} = mg\Delta y = (2m)g(2R\cos\theta_0)$.

$\Delta U_{grav\,(rod)} = mg\Delta y = mg(R\cos\theta_0)$

$\Delta U = 5mgR\cos\theta_0$.

This energy goes to rotation

$K_{rot} = \frac{1}{2}I\omega^2 = 5mgR\cos\theta_0$

$\frac{1}{2}\left(\frac{65}{6}mR^2\right)\omega^2 = 5mgR\cos\theta_0$

$\omega^2 = \frac{12}{13}\frac{g\cos\theta_0}{R}$

$\omega = \sqrt{\frac{12g\cos\theta_0}{13R}}$

$v = r\omega = 2R\sqrt{\frac{12g\cos\theta_0}{13R}}$

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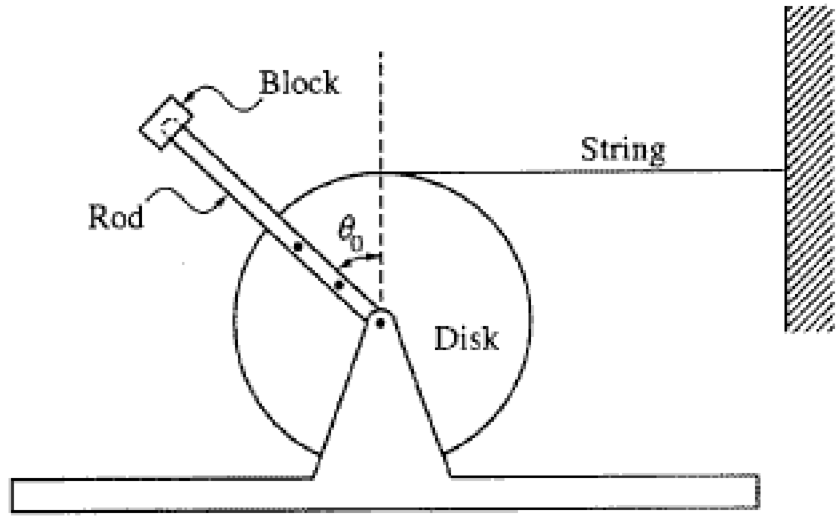

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(a) Determine the tension in the string.

$\Sigma \tau = I_{sys}\alpha$

$\alpha = 0$

$\Sigma \tau = 0$

$\tau_B + \tau_R - \tau_S = 0$

$\tau_B + \tau_R = \tau_S$

$(2R)(2mg)\sin\theta + (R)(mg)\sin\theta = T(R)\sin 90°$

$5mgR\sin\theta = RT$

$T = 5mg\sin\theta$

$I_{sys} = I_D + I_R + I_B = \frac{3}{2}mR^2 + \frac{4}{3}mR^2 + (2m)(2R)^2$

$I_{sys} = mR^2(\frac{3}{2} + \frac{4}{3} +$

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The string is now cut, and the disk-rod-block system is free to rotate.

(b) Determine the following for the instant immediately after the string is cut.

i. The magnitude of the angular acceleration of the disk

$I_{sys} = I_D + I_R + I_B = \frac{3}{2}mR^2 + \frac{4}{3}mR^2 + (2m)(2R)^2$

$I_{sys} = mR^2\left(\frac{3}{2} + \frac{4}{3} + 8\right) = \frac{65mR^2}{6}$

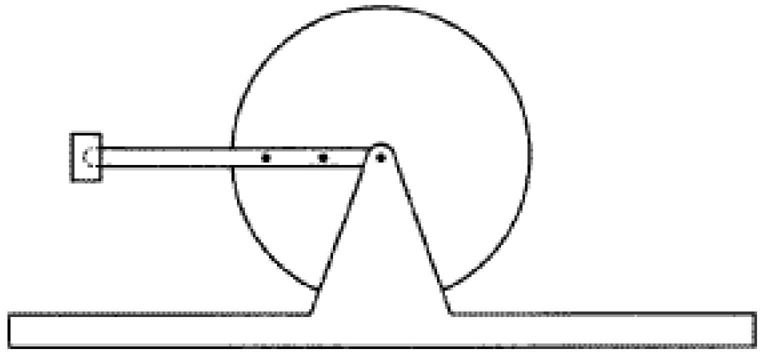
$\Sigma \tau = I\alpha$

$\alpha = \frac{\Sigma \tau}{I} = \frac{\tau_B + \tau_R}{I} = \frac{5mgR\sin\theta}{\frac{65mR^2}{6}} = \boxed{\frac{6g\sin\theta}{13R}}$

ii. The magnitude of the linear acceleration of the mass at the end of the rod

$a = \alpha(2R)$

$a = \frac{12g\sin\theta}{13}$



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(c) Determine the linear speed of the mass at the end of the rod for the instant the rod is in the horizontal position.

$\int_0^t a\,dt = v$

$|v| = \text{speed} = \left|\int_0^t a\,dt\right| = \left|at\big|_0^t\right| = |at|$ time and acceleration are positive

$= at$