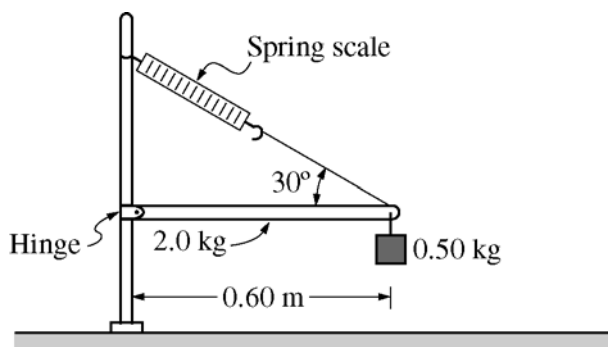


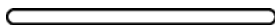
**2008 AP<sup>®</sup> PHYSICS C: MECHANICS FREE-RESPONSE QUESTIONS**



Mech. 2.

The horizontal uniform rod shown above has length 0.60 m and mass 2.0 kg. The left end of the rod is attached to a vertical support by a frictionless hinge that allows the rod to swing up or down. The right end of the rod is supported by a cord that makes an angle of  $30^\circ$  with the rod. A spring scale of negligible mass measures the tension in the cord. A 0.50 kg block is also attached to the right end of the rod.

- (a) On the diagram below, draw and label vectors to represent all the forces acting on the rod. Show each force vector originating at its point of application.



- (b) Calculate the reading on the spring scale.
- (c) The rotational inertia of a rod about its center is  $\frac{1}{12}ML^2$ , where  $M$  is the mass of the rod and  $L$  is its length. Calculate the rotational inertia of the rod-block system about the hinge.
- (d) If the cord that supports the rod is cut near the end of the rod, calculate the initial angular acceleration of the rod-block system about the hinge.

# AP<sup>®</sup> PHYSICS C: MECHANICS

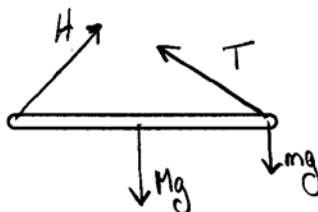
## 2008 SCORING GUIDELINES

### Question 2

15 points total

Distribution  
of points

(a) 4 points



For correctly drawing and labeling  $T$ , the tension in the cord, or its components

1 point

For correctly drawing and labeling  $Mg$ , the weight of the rod

1 point

For correctly drawing and labeling  $mg$ , the weight of the block

1 point

For correctly drawing or labeling  $H$ , the force exerted on the rod by the hinge, or its components

1 point

One earned point was deducted if one or more of the following were present: a correct vector not starting on the body, a component if the total force was also shown, or any extraneous vectors.

(b) 4 points

The reading on the scale is equal to the tension in the cord.

For an indication that the sum of the torques is equal to zero

1 point

$$\sum \tau = 0$$

For a correct expression for the torque exerted by the cord

1 point

For a correct expression for both the torque due to the weight of the rod and the torque due to the weight of the hanging block

1 point

The simplest method is to take the torque about the hinge, directly yielding an equation that can be solved for  $T$ . This is illustrated below. If the torque is taken about some other point, it must be combined with an equilibrium condition for the forces to eliminate the unknown  $H$ .

$$TL \sin 30^\circ - mgL - MgL/2 = 0$$

Solving for  $T$

$$TL \sin 30^\circ = mgL + MgL/2$$

$$T = \frac{g}{\sin 30^\circ} \left( m + \frac{M}{2} \right)$$

$$T = \frac{9.8 \text{ m/s}^2}{\sin 30^\circ} \left( 0.50 \text{ kg} + \frac{2.0 \text{ kg}}{2} \right)$$

For the correct answer (if previous 3 points were awarded)

1 point

$$T = 29 \text{ N} \quad (\text{or } 30 \text{ N using } g = 10 \text{ m/s}^2)$$

**AP<sup>®</sup> PHYSICS C: MECHANICS**  
**2008 SCORING GUIDELINES**

**Question 2 (continued)**

**Distribution  
of points**

(c) 3 points

For indicating that the rotational inertia of the system is the sum of the rotational inertia of both the rod and the hanging block 1 point

$$I_s = I_r + I_b$$

For using the correct rotational inertia of the rod about its end (either determining it using the parallel axis theorem or simply stating it) 1 point

$$I_r = I_{r,cm} + m\ell^2 = \frac{1}{12}ML^2 + M\left(\frac{L}{2}\right)^2 = \frac{4}{12}ML^2 = \frac{1}{3}ML^2$$

For a correct expression of the rotational inertia of the hanging block 1 point

$$I_b = mL^2$$

$$I_s = \frac{1}{3}ML^2 + mL^2$$

$$I_s = \frac{1}{3}(2.0 \text{ kg})(0.60 \text{ m})^2 + (0.50 \text{ kg})(0.60 \text{ m})^2 = (0.24 + 0.18) \text{ kg}\cdot\text{m}^2$$

$$I_s = 0.42 \text{ kg}\cdot\text{m}^2$$

(d) 3 points

For indicating that the sum of the torques is equal to  $I\alpha$  1 point

$$\sum \tau = I\alpha$$

For a correct summation of the torques about the hinge due to the block and rod 1 point

$$mgL + Mg\frac{L}{2} = I\alpha$$

$$\alpha = \frac{gL}{I}\left(m + \frac{M}{2}\right)$$

For substituting the rotational inertia calculated in part (c) 1 point

$$\alpha = \frac{(9.8 \text{ m/s}^2)(0.60 \text{ m})}{0.42 \text{ kg}\cdot\text{m}^2}\left(0.50 \text{ kg} + \frac{2.0 \text{ kg}}{2}\right)$$

$$\alpha = 21 \text{ radians/s}^2$$

Unit point

For correct units on all student answers 1 point