General Notes About 2008 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth 1 point and a student's solution contains the application of that equation to the problem, but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression, it is normally expected that they will begin by writing one or more fundamental equations such as those given on the AP Physics Exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description*.

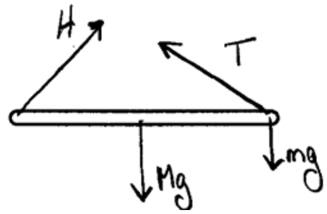
4. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but use of $10\ \text{m/s}^2$ is, of course, also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases, answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

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*.

$TL\sin 30° - mgL - MgL/2 = 0$

Solving for *T*

$TL\sin 30° = mgL + MgL/2$

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

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

For the correct answer (if previous 3 points were awarded) — 1 point

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

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

$I_b = mL^2$

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

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

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

(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

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

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

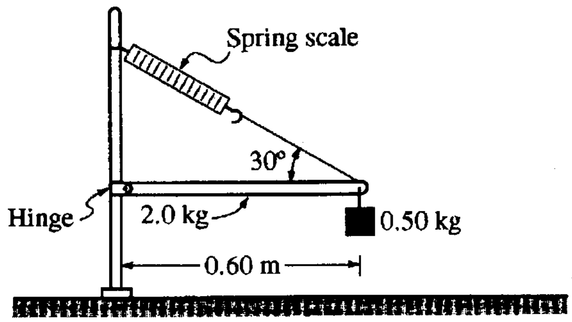
For substituting the rotational inertia calculated in part (c) — 1 point

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

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

Unit point

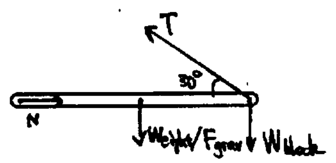
For correct units on all student answers — 1 point



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° 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.

~~∵ $\Sigma F_y = 0$ for equilibrium system~~

~~∴ $T \cdot \sin\theta = M_{rod} \cdot g + M_{block} \cdot g$.~~

~~⇒ $T \cdot \sin 30° = 2.0 \times 10 + 0.50 \times 10$.~~

~~$T = 50\ N$.~~

∵ equilibrium ∴ $\Sigma \tau = 0$.

⇒ $T \cdot l \cdot \sin 30° = M_{rod} \cdot g \cdot \frac{l}{2} + M_{block} \cdot g \cdot l$.

$T \cdot 0.60 \cdot \frac{1}{2} = 2.0 \cdot 9.8 \cdot \frac{0.6}{2} + 0.5 \cdot 9.8 \cdot 0.6$

$T = 29.4\ N$

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(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.

~~∵ hinge is parallel~~

∵ Axis-hinge // Axis-center of mass

∴ $I_p = I_{cm} + md^2 = \frac{1}{12}ML^2 + M\left(\frac{L}{2}\right)^2 = \frac{1}{3}ML^2$.

$\Sigma I = I_p + I_{block} = \frac{1}{3}M_{rod}L^2 + m_{block} \cdot L^2$

$= \frac{1}{3} \cdot 2.0 \cdot 0.6^2 + 0.50 \cdot 0.6^2$

$\doteq 0.42\ kg{\cdot}m^2$

(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.

$\tau = \Sigma F_i \cdot r_i = M_{rod} \cdot g \cdot \frac{\ell}{2} + m_{block} \cdot g \cdot \ell$

$= 2.0 \cdot 9.8 \cdot \frac{0.60}{2} + 0.50 \cdot 9.8 \cdot 0.60$.

$= 5.88 + 2.94$

$= 8.82\ N \cdot m$

$\Rightarrow \alpha = \frac{\tau}{I} = \frac{8.82}{0.42} = 21\ rad/s^2$

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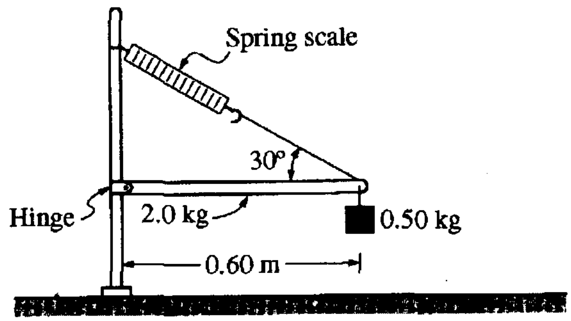

Mech. 2.

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° 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.

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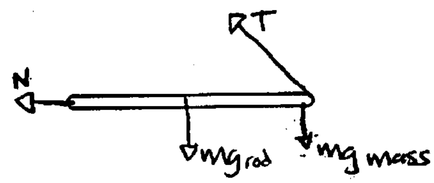

(b) Calculate the reading on the spring scale.

$\Sigma \tau = 0 = -m_{rod} g r - m_{mass} g r + T r \sin\theta$

$g(m_{rod} r + m_{mass} r) = T r \sin\theta$

$(9.81)(2 \cdot .3 + .5 \cdot .6) = T(.6)\sin(30)$

$\boxed{T = 117.72\,N}$

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(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.

By the parallel-axis thm

$= \frac{1}{12}ML^2 + Mr^2 + mr^2$

$= \frac{1}{12}(2)(.6)^2 + (2)(.3)^2 + (.5)(.3)^2$

$= .06 + .18 + .045$

$= \boxed{.285 \text{ kg·m}}$

(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.

$\tau = I\alpha$

$\alpha = \frac{\tau}{I}$

$\alpha = \frac{2.21}{.285}$

$\boxed{\alpha = 7.746 \frac{rad}{s^2}}$

$\Sigma\tau = (Mr^2 + mr^2)g + \cancel{\alpha}^{0}$

$= ((2)(.3)^2 + (.5)(.3)^2)(9.81)$

$= (.225)(9.81)$

$= 2.21 \text{ N·m}$

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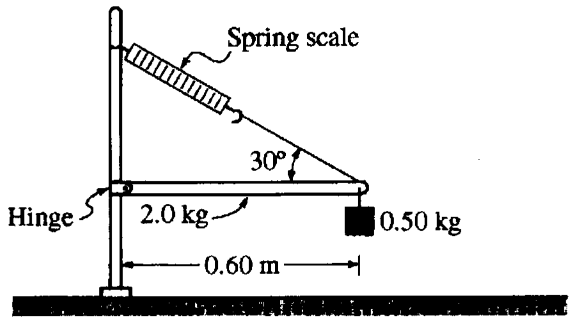

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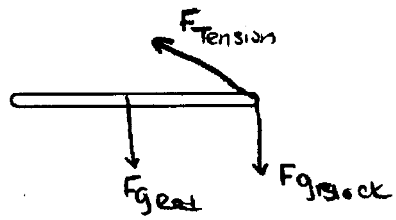

(b) Calculate the reading on the spring scale.

$F_T = Fg_{Block}$

$F_{T_y} = mg = (0.50\,kg)(9.8\,m/s^2)$

$F_{T_y} = 4.9\,N$

$\sin 30° = \frac{F_{Ty}}{T}$

$T = 9.8\,N$

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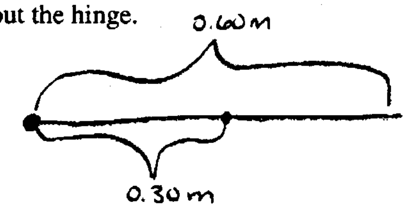
(c) The rotational inertia of a rod about its center is $\frac{1}{12}ML^2$, where M is the mass of the rod and L is its length. Calculate the rotational inertia of the rod-block system about the hinge.



$I = I_{com} + mh^2$

$I = \frac{1}{12}mL^2 + mh^2$

$I = (\frac{1}{12})(2.0\,kg)(0.60\,m)^2 + (2.0\,kg)(0.30\,m)^2$

$I = 0.24\ kg \cdot m^2$

(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.

$\tau = I\alpha$

$Fr = I\alpha$

$mgr = I\alpha$

$(0.5\,kg)(9.8\,m/s^2)(0.60\,m) = (0.24\,kg \cdot m^2)\alpha$

$\alpha = 12.25\ rad/s^2$

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AP® PHYSICS C: MECHANICS
2008 SCORING COMMENTARY

Question 2

Overview

This question was intended to assess students' ability to analyze forces and torques acting on a rigid body with a continuous mass distribution, specifically a rod with a block attached to one end and supported at either end by a hinge and a cord. Part (a) asked students to draw and label a free-body diagram in which forces and their points of application were shown. In part (b) they had to calculate the reading on the spring scale that connected the cord to the upper support. In part (c) students were asked to find the rotational inertia of the rod-block system about one end of the rod. Finally, in part (d) students were told that the cord was cut, and they were asked to find the initial angular acceleration of the rod-block system about the hinge.

Sample: CM2A
Score: 14

The only point not earned was that for the force from the hinge in part (a). Drawing only one correct component of that force was considered an incorrect direction for an existing force, not an extraneous force. The student initially attempts part (b) by summing forces but then correctly uses torque.

Sample: CM2B
Score: 10

Only 2 points were earned in part (a). There are three correct forces, and an incorrect force at the hinge that is considered as an extraneous force, so 1 point was deducted. In part (b) the student earned the points for applying the correct concept and the correct substitutions, but a calculation mistake is made so the answer point was lost. In part (c) the parallel axis theorem is used and the rotational inertia of the rod and block are added, but the calculation for the block is incorrect so only 2 points were earned. In part (d) the student makes an error in the calculation of torques and earned just 2 points. All units on final answers are correct, so the units point was earned.

Sample: CM2C
Score: 6

Three points were earned in part (a) for the forces shown. Part (b) shows a fairly common incorrect solution using forces that earned no credit. Part (c) earned 2 points for correctly using the parallel axis theorem. Part (d) does not show a sum of torques, so the only point earned was for substituting the rotational inertia found in part (c). All units on final answers are correct, so the units point was earned.