Smith's Key

A.P. Physics - C

UNIT 5 TEST REVIEW

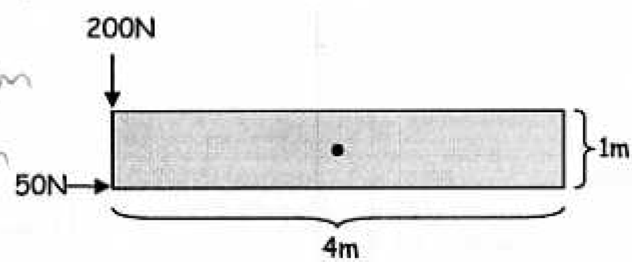
Rotational Motion

Chapter 10-12

*** In studying for your test, make sure to study this review sheet <u>along with your quizzes and homework assignments.</u>**

Multiple Choice Review: **On this portion of the test, you will not be allowed to use your calculator or AP formula sheet. (You may, however, use your AP table of information.) Approximate $g=10m/s^2$ for simplicity of calculations. No partial credit will be given.**

1. Calculate the net torque acting on the 5kg object, about an axis perpendicular to the page passing through its center.



a. 200Nm
b. 300Nm
c. 350Nm
d. 375Nm
(e.) 425Nm

$\tau_1 = 200(2) = 400Nm$ ccw
$\tau_2 = 50(.5) = 25Nm$ ccw

2. A 5m-radius disk starts from rest at t=0s and begins to rotate about its central axis with a rotational acceleration of $5rad/s^2$. How many radians has it passed through by the time t=4s?

$\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2}(5)(4^2) = 40$

a. 10 b. 20 (c.) 40 d. 80 e. 160

3. For the situation described in #2, what is the linear velocity, in meters per second, of a point on the disk's edge at time t=4s?

$\omega = \alpha t = (5)(4) = 20 \frac{rad}{s}$

a. 4 b. 20 c. 25 d. 50 (e.) 100

$v = r\omega = 5(20)$

4. A circular hoop of mass M and radius R rolls down an incline without slipping, from an initial height H. Its translational kinetic energy at the bottom of the incline is which one of the following?

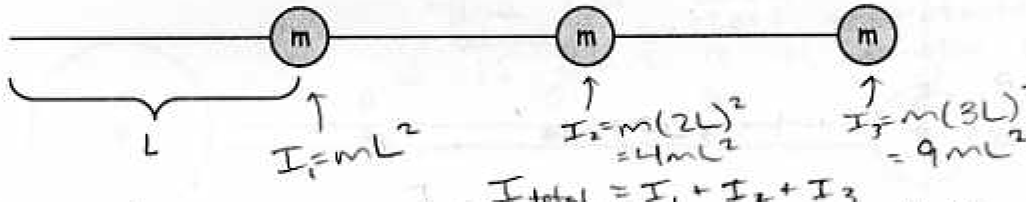
a. MgH
b. greater than MgH
(c) less than MgH
d. $\frac{1}{2}MR^2$
e. $\frac{1}{4}MR^2$

These aren't even energy values.

$MgH = KE_T + KE_R$

$KE_T = MgH - KE_R$

this must be less than MgH.



5. Three equal masses are connected at equal distances along a rod of length 3L and negligible mass. What is the moment of inertia about the left end of the rod?
   a. $3mL^2$ b. $9mL^2$ c. $14mL^2$ d. $17mL^2$ e. $27mL^2$

6. Which of the following objects is in static equilibrium?
   Object 1: A uniform teeter-totter with its fulcrum in its center, with equally-weighted children at its far ends. Yes
   Object 2: A merry-go-round slowing down under the action of friction. No!
   Object 3: A kickball that was initially kicked directly upward, now stopped momentarily at the highest point of its trajectory. No! (Forces aren't balanced.

   a. Object 1 only
   b. Object 2 only
   c. Object 3 only
   d. Objects 1 and 3
   e. Objects 1, 2, and 3

$\omega = \int \alpha\, dt = \int (3t^2)dt = t^3$
$\omega = 4^3 = 64$

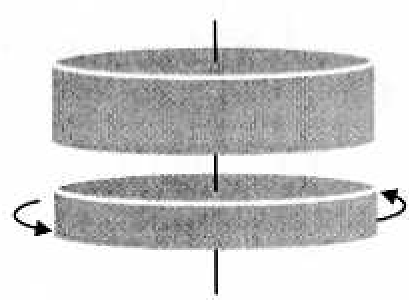
7. The rotational acceleration of an object as a function of time is given by $3t^2$. Calculate the rotational speed, in rad/s, of the object at time t=4 seconds.
   a. 12 b. 24 c. 40 d. 48 e. 64

8. A 1kg hoop of radius 2m is rotating about its center with an angular speed of 3rad/s. What is the rotational kinetic energy of the hoop?
   a. 4J b. 6J c. 12J d. 18J e. 20J

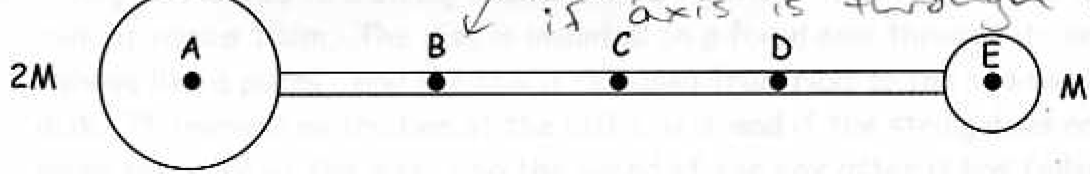
$KE = \frac{1}{2}I\omega^2 = \frac{1}{2}(MR^2)(\omega^2) = \frac{1}{2}(1)(2^2)(3^2) = 18J$

9. A disk of rotational inertia I is rotating about its central axis at an angular speed ω when a non-rotating disk of inertia 2I is dropped down to stick on top of the first disk and rotate with it. What is the angular speed of the 2-disk combination?
   a. $\frac{1}{3}\omega$
   b. $\frac{1}{2}\omega$
   c. ω
   d. 2ω
   e. 3ω

$L_i = L_f$
$I_i\omega_i = I_f\omega_f$
$I\omega = (3I)\omega_f$
$\frac{I\omega}{3I} = \omega_f$



The COM would be here, & it's always easiest to rotate (lower I) if axis is through COM.

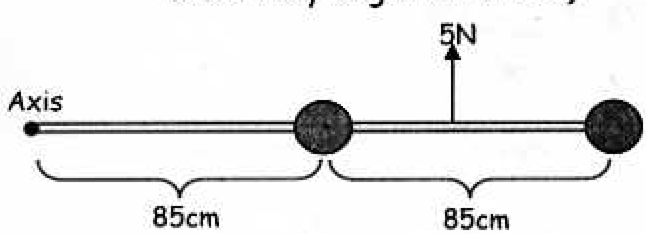


10. A sphere of mass M is connected to a sphere of mass 2M by a rigid rod of negligible mass, as shown in the above diagram. Which of the five lettered points is the best location for a perpendicular axis that will lead to the lowest rotational inertia, and therefore allow for the easiest rotation?

a. A (b.) B c. C d. D e. E

Problem Review: On this portion of the test, you may use your calculator, AP formula sheet, and AP table of information. Partial credit will be given on these problems.

11. Two masses on a frictionless horizontal plane, each with mass of 13kg, are attached to each other and to a rotation axis, by two 85cm-long thin rods of mass 8kg. The combination starts from rest, and is acted on by a 5N force that pulls perpendicularly to the length of the rods, at a location halfway between the two masses. (The force remains perpendicular to the rods even when they begin to rotate.)



a. Calculate the rotational inertia of the combination.

$I_{rod} = \frac{1}{12}ML^2 + mh^2 = \frac{1}{12}(16)(1.7^2) + (16)(.85^2) = 15.41 \text{ kgm}^2$

$I_{ball 2} = mr^2 = (13)(.85^2) = 9.39 \text{ kgm}^2$

$I_{ball 1} = mr^2 = (13)(1.7^2) = 37.57 \text{ kgm}^2$

b. Calculate the rotational acceleration of the combination. $I_{total} = 62.37 \text{ kgm}^2$

$\tau = I\alpha$

$5(1.275) = (62.37)(\alpha) \longrightarrow \alpha = 0.10 \frac{rad}{s^2}$

c. Calculate the rotational kinetic energy of the combination, 3 seconds after the 5N force begins acting.

$KE = \frac{1}{2}I\omega^2$

$= \frac{1}{2}(62.37)(.3^2)$

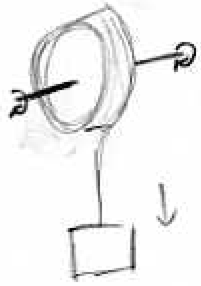
$= 2.81 \text{ J}$

$\omega = \omega_0 + \alpha t$

$\omega = \varnothing + (.1)(3)$

$= .3 \text{ rad/s}$

12. A 3kg box is tied to a string that is wound tightly around the outside of a 2kg disk of radius 15cm. The disk is mounted on a fixed axis through its center (to behave like a pulley), and the box is released from rest to fall and unwind the disk. If there is no friction at the disk's axis, and if the string does not slip along the edge of the disk, find the speed of the box after it has fallen 92cm.



$$mgh_i = \frac{1}{2}mv_f^2 + \frac{1}{2}I\omega^2$$

only the box changes h; only the box gains trans. KE; only the disk gains rot. KE; The edge of disk does same as ↓

$$3(9.8)(.92) = \frac{1}{2}(3)v_f^2 + \frac{1}{2}\left(\frac{1}{2}(2)(.15^2)\right)\left(\frac{v_f}{.15}\right)^2$$

$$27.05 = 1.5v_f^2 + .5v_f^2$$

$$27.05 = 2v_f^2$$

$$v_f = 3.68\ \text{m/s}$$

13. A solid sphere rolls without slipping down a 24° incline, from an initial height of 35cm above a tabletop.

a. Calculate the acceleration rate of the sphere as it rolls down the incline.

$$F_{gx} - F_{fric} = ma \qquad \tau = I\alpha$$

$$F_{fric}(r) = 2/5(mr^2)\left(\frac{a}{r}\right)$$

$$mg\sin\theta - 2/5\,ma = ma \qquad F_{fric} = \frac{2}{5}(ma)$$

$$(9.8)(\sin 24°) = \frac{7}{5}a$$

$$a = 2.85\ \text{m/s}^2$$

b. Use energy ideas to calculate the sphere's linear speed when it reaches the tabletop.

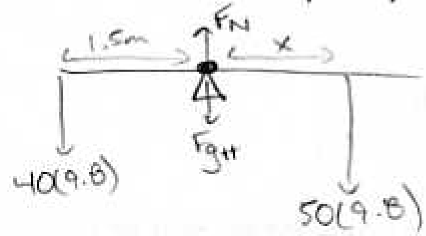
$$mgh_i = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$m(9.8)(.35) = \frac{1}{2}mv^2 + \frac{1}{2}(2/5)(mr^2)\left(\frac{v^2}{r^2}\right)$$

$$3.43 = 0.5v^2 + 0.2v^2$$

$$v = 2.21\ \text{m/s}$$

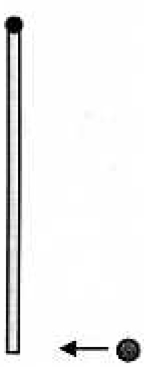
14. Two children balance on a 3m-long teeter-totter with the pivot point directly under the center of the teeter-totter. The child on the left end has a mass of 40kg and sits on the edge of her seat. The child on the right has a mass of 50kg and must scoot in some from the edge in order to balance. How far from the pivot point does the child on the right sit?



$$392(1.5) = 490x$$

$$x = 1.2\text{m}$$

15. A 78cm-long uniform rod with rotational inertia of 0.15kgm^2 is initially hanging vertically from a pivot point at its top end. The rod is struck at its bottom end by a 200g ball of putty, moving at 4m/s to the left. If the putty sticks to the rod upon colliding with its, calculate the angular speed of the rod-putty combination directly after the collision.



$$L_i = L_f$$

(L_i: ball; L_f: ball & rod)

$$I = 0.15 + (.2)(.78)^2 = .272$$

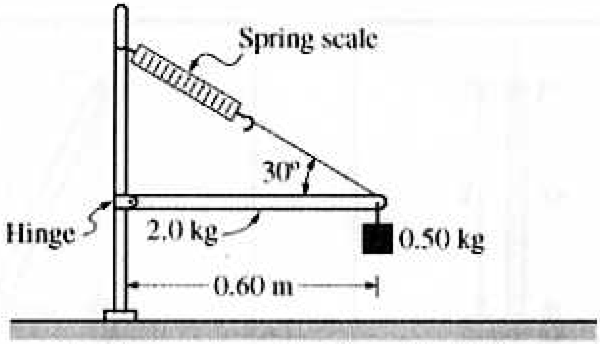
(0.15: rod; $(.2)(.78)^2$: ball)

$$rmv = I\omega$$

$$(.78)(.2)(4) = (.272)(\omega)$$

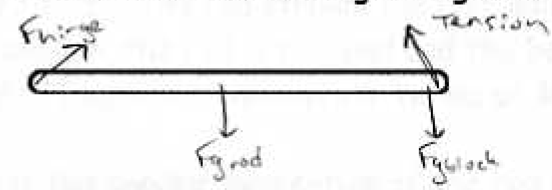
$$\omega = 2.30 \text{ rad/s}$$

16. Actual A.P. Physics C Free-Response Question (2008):



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.

$\tau_{cw} = \tau_{ccw}$

$(2)(9.8)(.3) + (.5)(9.8)(.6) = T(\sin 30)(.6)$

$8.82 = .3T \longrightarrow T = 29.4N$

c. The rotational inertia of a rod about its center is $\frac{1}{12}ML^2$. Calculate the rotational inertia of the rod-block system about the hinge.

$I = \left(\frac{1}{12}ML^2 + Mh^2\right) + mr^2$

$= \frac{1}{12}(2)(.6^2) + (2)(.3^2) + (.5)(.6^2) = .42\ kgm^2$

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.

$\tau = I\alpha$

$8.82 = .42\alpha$

$\alpha = 21\ \frac{rad}{s^2}$