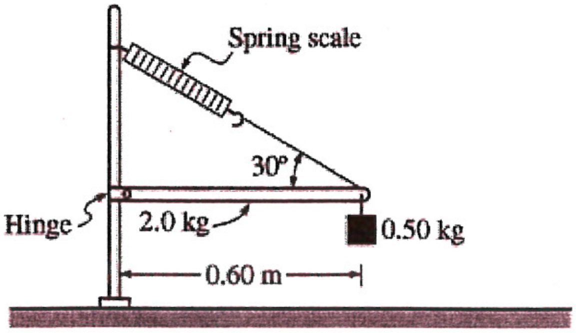
Name: KEY

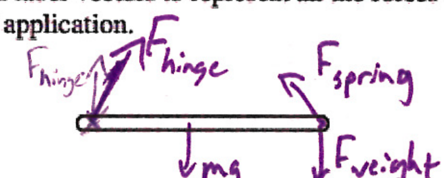
Rotation Practice/Review Problems



1.

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, which is the tension in the cord. This is the same type of problem s the balancing meter stick; choose your pivot to be the hinge. If there is an angle, use T=~~Iαsin~~Θ.

$T = F r \sin\Theta$

$\Sigma\tau = 0$ ↻+

$mg\cdot(0.3\,m) + 0.5kg\cdot g\cdot(0.6m) - F_{spring}\cdot 0.6m\cdot\sin 30 = 0$

$20N\cdot 0.3m + 5N\cdot 0.6m = F_{spring}\cdot 0.3m$

$30\,N = F_{spring}$

(c) The string is now cut. Is the initial linear acceleration at the center of the rod greater than, less than, or equal to g? The rotational inertia of the rod is 1/12mL2. (Hint: Find angular acceleration first, then use a=αR to find a)

$I\alpha = \Sigma\tau$

$\frac{1}{12}\cdot mL^2\alpha = 6\,N\cdot m + 3\,Nm$

$\alpha = \frac{12\cdot 9}{(0.6)^2\cdot 2.0} = 150\,rad/s^2$

$a = r\alpha$

$= 0.3m\cdot 150\,rad/s^2$

$= 45\,m/s^2$ Woah!

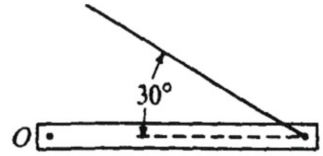
This is not technically correct because the I is wrong, but just understand that the connection between I + α is $\Sigma\tau = I\alpha$

(d) i. When the rod was released, is the angular acceleration of the end of the rod greater than, less than, or equal to the angular acceleration of the center of mass? Explain.

Same. Since the rod stays together, it must all be rotating at the same angular rate.

ii. When the rod was released, is the linear acceleration of the end of the rod greater than, less than, or equal to the linear acceleration of the center of mass? Explain.

Greater. Same α, but greater distance from pivot means greater accel (linear).



4. A uniform rigid bar of weight W is supported in a horizontal orientation as shown above by a rope that makes a 30° angle with the horizontal. The force exerted on the bar at point O, where it is pivoted, is best represented by a vector whose direction is which of the following?

because the rope is pulling inward the wall must push inward

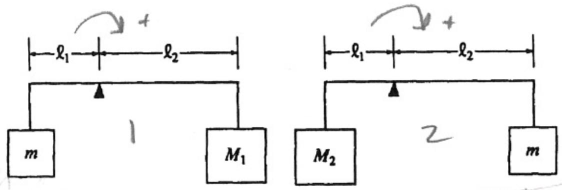
(A) ↑ (B) ↗ (C) → (D) ↘

$\Sigma\tau_1 = 0 = -mg\ell_1 + M_1 g \ell_2$

$\ell_1 = \frac{M_1 \ell_2}{m}$

$\Sigma\tau_2 = 0 = mg\ell_2 - M_2 g \ell_1$

$\ell_1 = \frac{m\ell_2}{M_2}$



$\frac{M_1 \ell_2}{m} = \frac{m \ell_2}{M_2}$

$m^2 = M_1 M_2$

$m = \sqrt{M_1 M_2}$

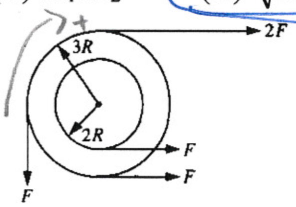
5. A rod of negligible mass is pivoted at a point that is off-center, so that length l_1 is different from length l_2. The figures above show two cases in which masses are suspended from the ends of the rod. In each case the unknown mass m is balanced by a known mass, M_1 or M_2, so that the rod remains horizontal. What is the value of m in terms of the known masses?

(A) $M_1 + M_2$ (B) $\frac{1}{2}(M_1 + M_2)$ (C) $M_1 M_2$ (D) $\sqrt{M_1 M_2}$

3R

$\Sigma\tau = 3r(2F - F - F)$

$= 0$



2R

$\Sigma\tau = 2R(-F)$

$= -2RF$

6. A system of two wheels fixed to each other is free to rotate about a frictionless axis through the common center of the wheels and perpendicular to the page. Four forces are exerted tangentially to the rims of the wheels, as shown above. The magnitude of the net torque on the system about the axis is

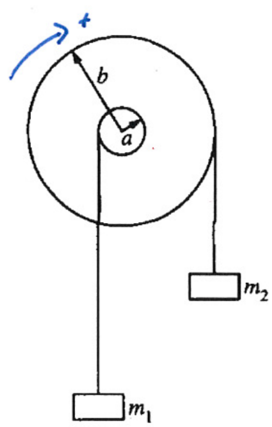
(A) FR (B) 2FR (C) 5FR (D) 14FR

a

$m_1 g$

b

$m_2 g$



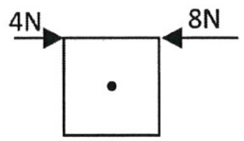
$\Sigma\tau = \tau_a + \tau_b$

$= -m_1 g a + m_2 g b$

$m_1 a = m_2 b$

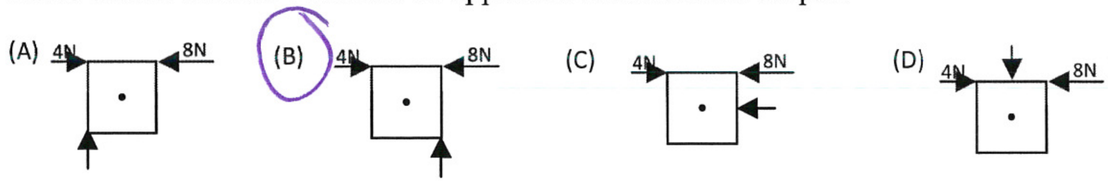
7. For the wheel-and-axle system shown above, which of the following expresses the condition required for the system to be in static equilibrium?

(A) $m_1 = m_2$ (B) $am_1 = bm_2$ (C) $am_2 = bm_1$ (D) $a^2m_1 = b^2m^2$

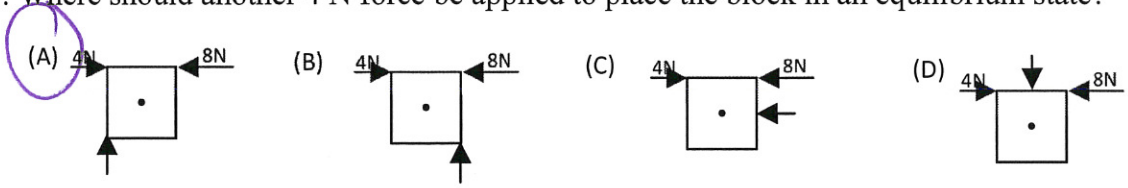


A wooden square of side length 1.0 m is on a horizontal tabletop and is free to rotate about its center axis. The square is subject to two forces and rotates.

23. Where should another 4 N force be applied to maximize its torque?

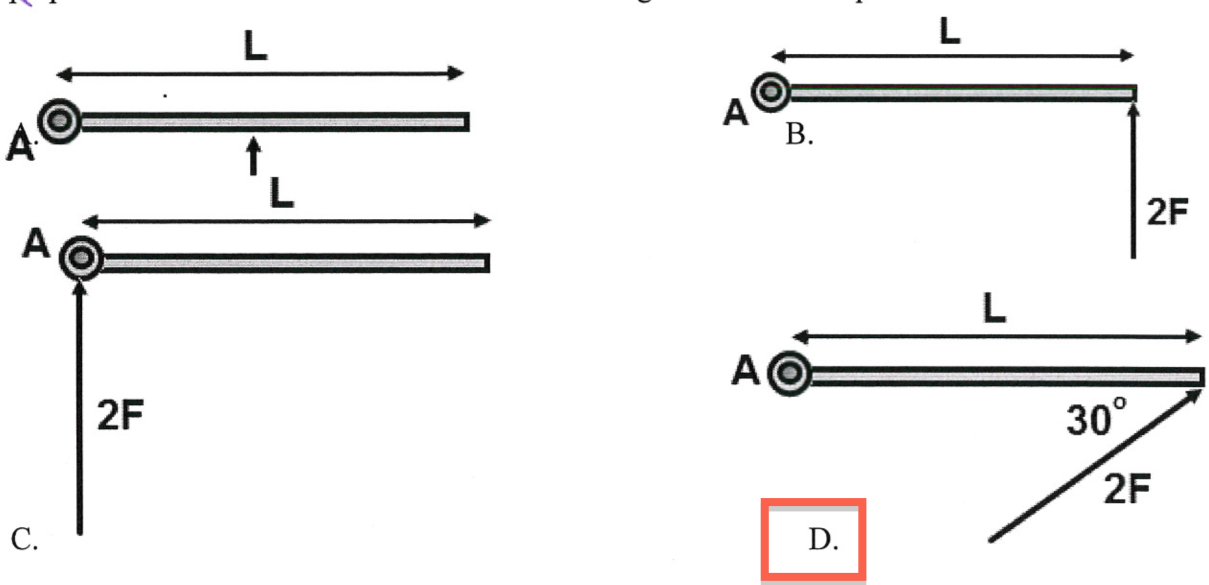


24. Where should another 4 N force be applied to place the block in an equilibrium state?



~~Woops, no original picture.~~

25. As shown above, a rod with a length L is free to rotate about point A. An external force F is applied perpendicular to the rod. In which of the following cases is the torque on the rod the same as the above?

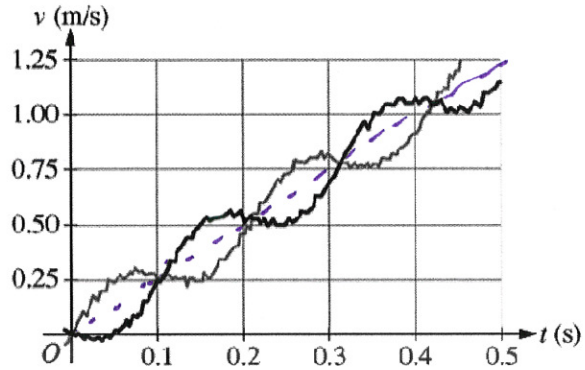


26. A student spins on a turn table. If his arms are pulled in closer to his body, describe the impact of his motion on his arms on the angular momentum and kinetic energy.

Brings mass into a smaller radius, I goes down, momentum is conserved, so ω must increase.

$L = I\omega$

Pulling his arms in does work on the system so KE will increase.



27. A student on another planet has two identical spheres, each of mass 0.6 kg, attached to the ends of a rod of negligible mass. The student gives the assembly a rotation in the vertical plane and then releases it so it falls, as shown in the top figure above. Sensors record the vertical velocity of the two spheres, and the data is shown in the graph of velocity v as a function of time t. Another student wants to calculate the assembly's angular speed and the change in the linear momentum of the center of mass of the assembly between 0 s and 0.3 s. Which of these quantities can be determined using the graph?

(A) Angular speed only

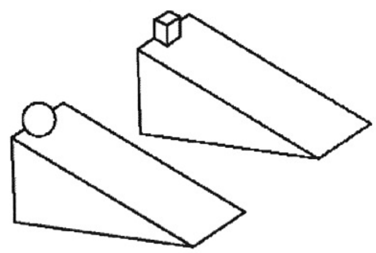
(B) Change in linear momentum only

(C) Angular speed and change in linear momentum

(D) Neither of these quantities can be determined using the graph.

slope gives CM speed

Look at period of oscillation



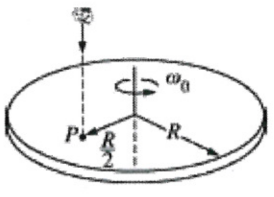
28. Two objects are released from rest at the top of ramps with the same dimensions, as shown in the figure above. The sphere rolls down one ramp without slipping. The small block slides down the other ramp without friction. Which object reaches the bottom of its ramp first, and why?

(A) The sphere, because it gains rotational kinetic energy, but the block does not

(B) The sphere, because it gains mechanical energy due to the torque exerted on it, but the block does not

(C) The block, because it does not lose mechanical energy due to friction, but the sphere does

(D) The block, because it does not gain rotational kinetic energy, but the sphere does



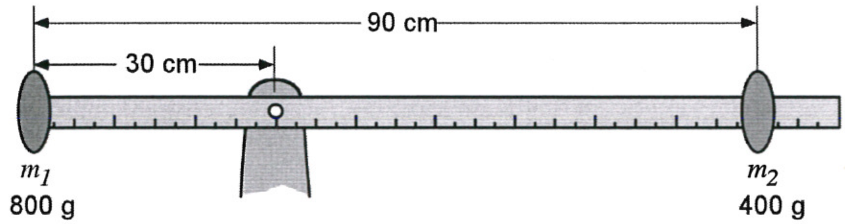
29.

A turntable with mass m, radius R, and rotational inertia $\frac{mR^2}{2}$ initially rotates freely about an axis through its center at constant angular speed with negligible friction. A piece of clay, also of mass m, falls vertically onto the turntable, as shown above, and sticks to it at point P, a distance $\frac{R}{2}$ from the center of rotation.

What happens to the rotational speed of the turntable and the angular momentum of the clay-turntable system about the axis as a result of the collision?

	Rotational Speed	Angular Momentum
(A)	Stays the same	Increases
(B)	Stays the same	Stays the same
(C)	Stays the same	Decreases
(D)	Decreases	Stays the same
(E)	Decreases	Decreases

30. A massless meter stick is free to rotate about a frictionless pin at the 30-cm mark. An 800-gram mass labeled m_1 is attached to the end of the meter stick at the zero cm mark and a 400-gram mass labeled m_2 is attached to the 90 cm mark.



a) Is the rotational inertia of mass m_1 about the pivot pin *greater than, less than,* or *equal to* the rotational inertia of mass m_2 about the pivot point?

Explain. $I = mr^2$ for point masses.
$m_1 \rightarrow m_2$ has $\frac{1}{2}$ mass, but double the radius,
so $I_2 > I_1$

b) Does the rotational inertia of the meter stick system about the pivot point *increase, decrease,* or *remain the same* if it rotates 90° from the horizontal orientation shown to a vertical orientation with mass m_2 upward?

Explain. Same. Orientation doesn't matter.

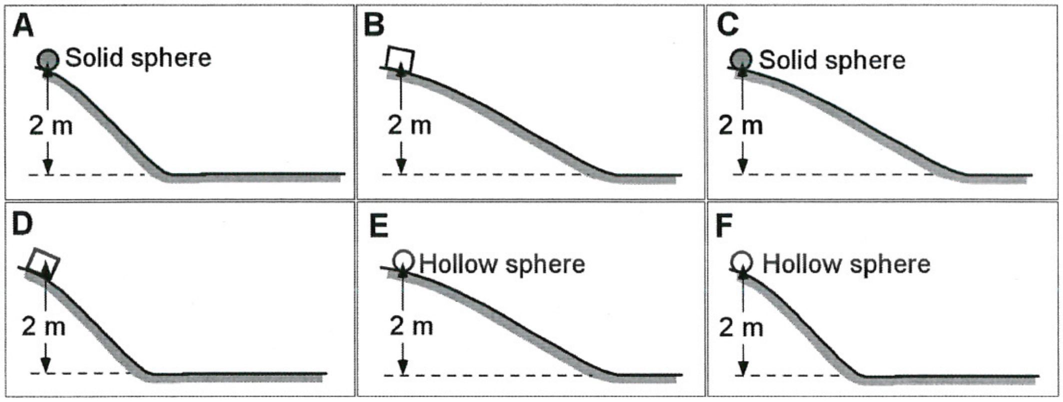
c) If the meter stick system is rotating at a constant angular velocity about the pivot pin, is the angular momentum of mass m_1 *greater than, less than,* or *equal to* the angular momentum of mass m_2?

Explain. Both have same ω, but $I_2 > I_1$
so $L_2 > L_1$ $(L = I\omega)$

d) If the meter stick system is rotating at a constant angular velocity about the pivot pin, is the kinetic energy of mass m_1 *greater than, less than,* or *equal to* the kinetic energy of mass m_2?

Explain. Both have same ω, but $I_2 > I_1$
so $KE_2 > KE_1$ $(KE = \frac{1}{2} I\omega^2)$

31. In each case below, a 1-kg object is released from rest on a ramp at a height of 2 meters from the bottom. All of the spheres roll without slipping, and the blocks slide without friction. The ramps are identical in cases A, D, and F. The ramps in cases B, C, and E are identical and are not as steep as the others.



Rank these cases on the basis of the speed of the objects when they reach the horizontal surface at the bottom of the ramp.

Greatest 1 B = 2 D 3 A = 4 C 5 E = 6 F Least

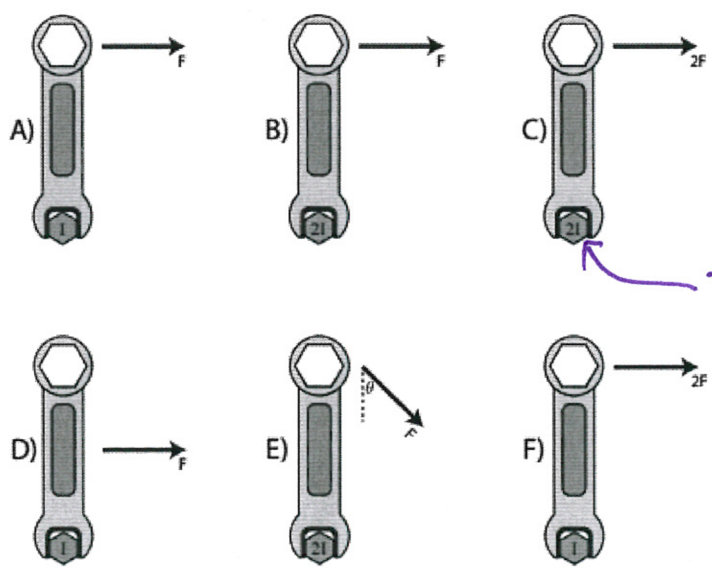
OR, The maximum speed is the same for all cases. ___

OR, We cannot determine the ranking for the maximum speed of these objects. ___

Please explain your reasoning.

- Hollow spheres have most mass far out → higher I than solid.
- Length of path doesn't matter, only starting GPE.

32. A given force is applied to a wrench to turn a bolt of specific rotational inertia I which rotates freely about its center as shown in the following diagrams. Which of the following correctly ranks the resulting angular acceleration of the bolt?



(A) $\alpha_F > \alpha_A = \alpha_C > \alpha_B = \alpha_D > \alpha_E$

(B) $\alpha_C = \alpha_F > \alpha_A = \alpha_B > \alpha_D > \alpha_E$

(C) $\alpha_A = \alpha_F > \alpha_C = \alpha_E > \alpha_B = \alpha_D$

(D) $\alpha_D = \alpha_F > \alpha_A = \alpha_C > \alpha_B > \alpha_E$

Can't really rank without knowing θ

Those marks don't matter.