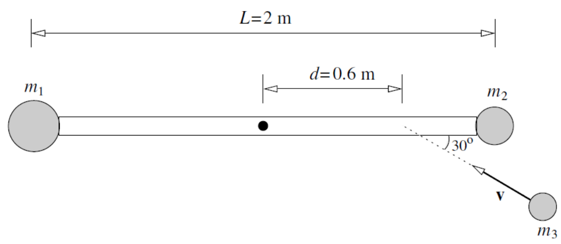
P1 [2009-2010 Fall - Final]: Two point particles with masses $m_1 = 5$ kg and $m_2 = 3$ kg are connected to the ends of a rod of length $L = 2$ m and mass $M = 4$ kg, as shown in the figure. This {rod + particles} system is initially at rest on a horizontal plane and free to rotate about a fixed frictionless rotation axis passing through the center of mass of the rod. A lump of clay of mass $m_3 = 1$ kg, moving with speed v in the direction as depicted in the figure, collides and sticks to the rod at a point 0.6 m away from the axis of rotation. (a) Find the rotational inertia of the {rod + particles + clay} system after the collision. (b) If the {rod + particles + clay} rotates system with an angular speed 3 rad/s just after the collision, what is the speed v of the clay before the collision? (The rotational inertia of rod is $\frac{1}{12}ML^2$.)



SOLUTION: $m_1 = 5$ kg, $m_2 = 3$ kg, $m_3 = 1$ kg, $M = 4$ kg, $L = 2$ m, $d = 0.6$ m, $\omega_f = 3$ rad/s, $\theta = 30^\circ$, $I_{rod} = \frac{1}{12}ML^2$

(a) The rotational inertia of the whole system after the collision is

$$I_f = I_{rod} + I_1 + I_2 + I_3 = \tfrac{1}{12}ML^2 + m_1\left(\frac{L}{2}\right)^2 + m_2\left(\frac{L}{2}\right)^2 + m_3 d^2$$

$$= \left(\tfrac{1}{12}\right)(4)(2)^2 + (5)\left(\tfrac{2}{2}\right)^2 + (3)\left(\tfrac{2}{2}\right)^2 + (1)(0.6)^2 = 9.6933\ \text{kg}\cdot\text{m}^2 \approx 9.69\ \text{kg}\cdot\text{m}^2 \quad ☺$$

(c) The angular momentum of the whole system before the collision is due only to the moving lump of clay:

$$L_i = \ell_3 = m_3 v_\perp d = m_3 \cdot v\sin\theta \cdot d = m_3 v d \sin\theta$$

With this, the conservation of angular momentum yields

$$L_i = L_f \;\Rightarrow\; m_3 v d\sin\theta = I_f\omega_f \;\Rightarrow\; v = \frac{I_f\omega_f}{m_3 d\sin\theta} = \frac{(9.6933)(3)}{(1)(0.6)\sin 30^\circ} \approx 96.9\ \text{m/s} \quad ☺$$

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P2 [2009-2010 Spring - Final][E]: A man stands on a platform that is rotating without friction with an angular speed of 1.2 rev/s; his arms are outstretched and he holds a brick in each hand. The rotational inertia of the system $6\ \text{kg}\cdot\text{m}^2$. The man pulls in his arms and decreases the rotational inertia of the system to $2\ \text{kg}\cdot\text{m}^2$. (a) Find the resulting angular speed of the platform. (b) Calculate the ratio of the new kinetic energy of the system to the original kinetic energy. (c) What source provides the added kinetic energy, if the ratio calculated in part (b) is greater than unity?

SOLUTION: $\omega_1 = 1.2$ rev/s, $I_1 = 6\ \text{kg}\cdot\text{m}^2$, $I_2 = 2\ \text{kg}\cdot\text{m}^2$

(a) $I_1\omega_1 = I_2\omega_2 \;\Rightarrow\; \omega_2 = \frac{I_1}{I_2}\omega_1 = \frac{6}{2}(1.2) = 3.60$ rev/s ☺

(b) $\frac{K_2}{K_1} = \frac{\frac{1}{2}I_2\omega_2^2}{\frac{1}{2}I_1\omega_1^2} = \frac{I_2}{I_1}\left(\frac{\omega_2}{\omega_1}\right)^2 = \frac{2}{6}\left(\frac{3.6}{1.2}\right)^2 = 3.00$ ☺

(c) Because no external agent does work on the system, the extra energy comes from the internal energy of the man.

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P3 [2009-2010 Summer - Final][E]: A merry-go-round of radius $2\ \text{m}$ has a moment of inertia $250\ \text{kg}\cdot\text{m}^2$ and is rotating at $10\ \text{rev/min}$ about a frictionless vertical axle. A 30-kg dog hops onto the merry-go-round and stays on the edge. What is the new angular speed of the merry-go-round, in rev/min?

SOLUTION: $r = 2\ \text{m}$, $I = 250\ \text{kg}\cdot\text{m}^2$, $\omega_1 = 10\ \text{rev/min}$, $m = 30\ \text{kg}$

$$L_1 = L_2 \Rightarrow I_1\omega_1 = I_2\omega_2 \Rightarrow I\omega_1 = (I + mr^2)\omega_2$$

$$\Rightarrow \omega_2 = \frac{I\omega_1}{I + mr^2} = \frac{(250)(10)}{250 + (30)(2^2)} \approx 6.76\ \text{rev/min}$$ ☺

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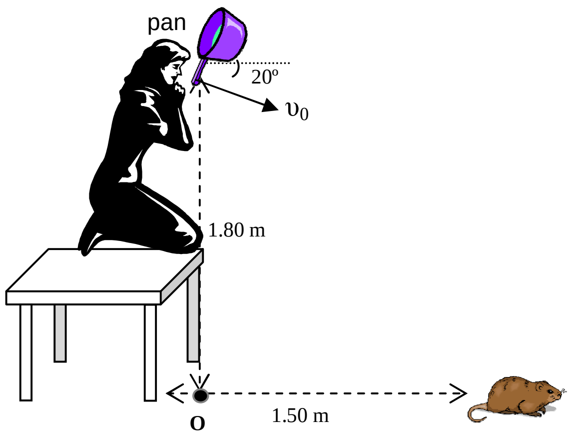
P4 [2010-2011 Fall - Final]: A housewife sees a rat in her kitchen and the poor frightened woman jumps onto the kitchen table with a pan in her hand. She wants to hit the rat by throwing the pan; however the rat also starts running away with 2.7 m/s (assume constant) as soon as he notices the danger. At the moment she throws the pan, the rat is 1.5 m away from the table. (a) With what initial speed must she throw the pan to hit the rat? (b) **(BONUS: +5 points)** What is the angular momentum of the pan, weighing $0.75\ \text{kg}$, $0.2\ \text{s}$ after it was thrown with respect to point O, *in unit vector notation*?



SOLUTION: $v' = 2.7\ \text{m/s}$, $x'_0 = 1.5\ \text{m}$, $y_0 = 1.8\ \text{m}$, $\theta_0 = 20^\circ$

(a) For the pan:

$$y = 0 = y_0 + v_{y0}t - \tfrac{1}{2}gt^2 \Rightarrow 0 = y_0 + (-v_0\sin\theta_0)t - \tfrac{1}{2}gt^2$$

$$\Rightarrow \tfrac{1}{2}gt^2 + tv_0\sin\theta_0 - y_0 = 0 \quad (1)$$

$$x = x_0 + v_xt = 0 + (v_0\cos\theta_0)t \Rightarrow x = tv_0\cos\theta_0 \quad (2)$$

For the rat:

$$x' = x'_0 + v't \quad (3)$$

The two distances x and x' must be equal to each other:

$$x = x' \;\Rightarrow\; t\,v_0\cos\theta_0 = x'_0 + v't \;\Rightarrow\; v_0 = \frac{x'_0 + v't}{t\cos\theta_0} \qquad (4)$$

Feed this into Eq.(1):

$$\tfrac{1}{2}gt^2 + t\left(\frac{x'_0 + v't}{t\cos\theta_0}\right)\sin\theta_0 - y_0 = 0 \;\Rightarrow\; \tfrac{1}{2}gt^2 + (x'_0 + v't)\tan\theta_0 - y_0 = 0$$

$$\Rightarrow\; \tfrac{1}{2}gt^2 + (v'\tan\theta_0)t + x'_0\tan\theta_0 - y_0 = 0$$

This is a quadratic equation in t, whose solution is

$$t = \frac{-v'\tan\theta_0 + \sqrt{(v'\tan\theta_0)^2 - (4)(\tfrac{1}{2}g)(x'_0\tan\theta_0 - y_0)}}{(2)(\tfrac{1}{2}g)}$$

$$\Rightarrow\; t = \frac{-v'\tan\theta_0 + \sqrt{(v'\tan\theta_0)^2 - 2g\,(x'_0\tan\theta_0 - y_0)}}{g}$$

$$\Rightarrow\; t = \frac{-2.7\tan 20^\circ + \sqrt{(2.7\tan 20^\circ)^2 - (2)(9.8)(1.5\tan 20^\circ - 1.8)}}{9.8} = 0.41546\text{ s}$$

Then, the initial velocity of the pan, from Eq.(4), is

$$v_0 = \frac{x'_0 + v't}{t\cos\theta_0} = \frac{1.5 + (2.7)(0.41546)}{0.41546\cos 20^\circ} = 6.7154\text{ m/s} \approx 6.72\text{ m/s} \qquad ☺$$

(b) $m = 0.75\text{ kg}$, $t = 0.2\text{ s}$

$$x = (v_0\cos\theta_0)t = (6.7154\cos 20^\circ)(0.2) = 1.2621\text{ m}$$
$$y = y_0 - (v_0\sin\theta_0)t - \tfrac{1}{2}gt^2 = 1.8 - (6.7154\sin 20^\circ)(0.2) - (\tfrac{1}{2})(9.8)(0.2)^2 = 1.1446\text{ m}$$

These give

$$\vec{r} = (1.1446\,\hat{\text{i}} + 1.2621\,\hat{\text{j}})\text{ m}$$

$$v_x = v_0\cos\theta_0 = 6.7154\cos 20^\circ = 6.3104\text{ m/s}$$
$$v_y = v_{y0} - gt = -v_0\sin\theta_0 - g\,t = -6.7154\sin 20^\circ - (9.8)(0.2) = -4.2568\text{ m/s}$$

Therefore,

$$\vec{v} = (6.3104\,\hat{\text{i}} - 4.2568\,\hat{\text{j}})\text{ m/s}$$

$$\vec{\ell} = m\,\vec{r}\times\vec{v} = 0.75\,(1.1446\,\hat{\text{i}} + 1.2621\,\hat{\text{j}})\times(6.3104\,\hat{\text{i}} - 4.2568\,\hat{\text{j}})$$

$$\Rightarrow \quad \vec{\ell} = -(0.75)(1.1446)(4.2568)\,\hat{\imath}\times\hat{\jmath} + (0.75)(1.2621)(6.3104)\,\hat{\jmath}\times\hat{\imath}$$

$$\Rightarrow \quad \vec{\ell} = -3.6542\,\hat{k} + 5.9733(-\hat{k}) \approx (-9.63\,\hat{k})\ \mathrm{kg\cdot m^2/s^2} \qquad ☺$$

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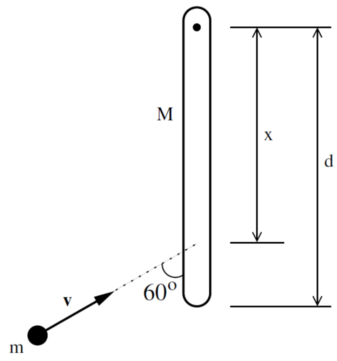
P5 [2010-2011 Fall - Final]: A thin stick of mass M and length d is attached to a pivot at the top. A piece of clay of mass $m = M/3$ and speed v hits the stick a distance $x = 2d/3$ from the pivot and sticks to it, as shown in the figure. The rotational inertia of the stick about the pivot is $\frac{1}{3}Md^2$. Find the ratio of the final kinetic energy (just after the collision) to the initial kinetic energy (just before the collision) of the {stick + clay} system.



SOLUTION:

First note the following which makes the problem easier:

$$K = \tfrac{1}{2}I\omega^2 = \frac{(I\omega)^2}{2I} = \frac{L^2}{2I}$$

Before the collision, the only angular momentum, about the pivot, is due to the clay:

$$L_\mathrm{i} = \ell_\mathrm{i} = mrv_\perp = m\cdot x\cdot v\sin 60^\mathrm{o} = mxv\cdot\frac{\sqrt{3}}{2} \quad\Rightarrow\quad L_\mathrm{i} = \frac{\sqrt{3}}{2}mxv$$

The conservation of angular momentum requires that

$$L_\mathrm{f} = L_\mathrm{i} = \frac{\sqrt{3}}{2}mxv$$

The rotational inertia about the pivot, after the collision, is

$$I_\mathrm{f} = I_\mathrm{rod} + I_\mathrm{clay} = \tfrac{1}{3}Md^2 + mx^2 = \tfrac{1}{3}\cdot 3m\cdot\left(\frac{3x}{2}\right)^2 + mx^2 \quad\Rightarrow\quad I_\mathrm{f} = \frac{13}{4}mx^2$$

Therefore, the desired ratio is

$$\frac{K_\mathrm{f}}{K_\mathrm{i}} = \frac{L_\mathrm{f}^2/2I_\mathrm{f}}{K_\mathrm{i}} = \frac{L_\mathrm{f}^2}{2I_\mathrm{f}\,K_\mathrm{i}} = \frac{\left(\frac{\sqrt{3}}{2}mxv\right)^2}{2\cdot\left(\frac{13}{4}mx^2\right)\cdot\frac{1}{2}mv^2} = \frac{\frac{3}{4}(mxv)^2}{\frac{13}{4}(mxv)^2} \quad\Rightarrow\quad \frac{K_\mathrm{f}}{K_\mathrm{i}} = \frac{3}{13} \approx 0.231 \qquad ☺$$

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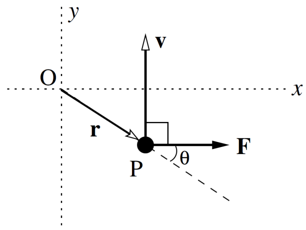
P6 [2010-2011 Summer - Final][E]: At one instant, a $5\ \text{kg}$ particle P has a position vector $\vec{r}$ of magnitude $4\ \text{m}$ and an angle $\theta = 33.7^\circ$, and a velocity vector $\vec{v}$ of magnitude $5\ \text{m/s}$. Force $\vec{F}$ of magnitude $3\ \text{N}$ acts on P. All three vectors lie in the xy-plane. *About the origin*, (a) what are the magnitude and direction of the angular momentum of P?, (b) what are the magnitude and direction of the torque acting on P?



SOLUTION: $m = 5\ \text{kg}$, $r = 4\ \text{m}$, $\theta = 33.7^\circ$, $v = 5\ \text{m/s}$, $F = 3\ \text{N}$

(a) $\vec{\ell} = \vec{r} \times \vec{p} = \vec{r} \times m\vec{v} = m\vec{r} \times \vec{v} = mrv\sin(90^\circ + \theta)\hat{\text{k}}$

$$= (5)(4)(5)\sin(90^\circ + 33.7^\circ)\hat{\text{k}} \approx (83.2\ \text{kg}\cdot\text{m}^2/\text{s})\hat{\text{k}}$$ ☺

(b) $\vec{\tau} = \vec{r} \times \vec{F} = rF\sin\theta\,\hat{\text{k}} = (4)(3)\sin 33.7^\circ\,\hat{\text{k}} \approx (6.66\ \text{N}\cdot\text{m})\hat{\text{k}}$ ☺

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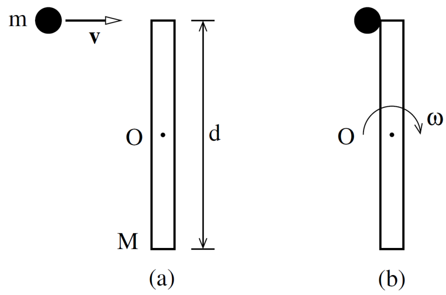
P7 [2010-2011 Summer - Final]: A projectile of mass $m = 0.5\ \text{kg}$ moves to the right with a speed $v = 12\ \text{m/s}$. The projectile strikes and sticks to the end of a stationary rod of mass $M = 2.2\ \text{kg}$ and length $d = 1.4\ \text{m}$, pivoted about a frictionless axle through its center. (a) Find the angular speed ω *just after* the collision. (b) Determine the fractional loss in mechanical energy due to the collision. (The rotational inertia of the rod about its center of mass is $I_{\text{rod}} = \frac{1}{12}Md^2$.)



SOLUTION: $m = 0.5\ \text{kg}$, $v = 12\ \text{m/s}$, $M = 2.2\ \text{kg}$, $d = 1.4\ \text{m}$

(a) The rotational inertia of the system about pivot point O is

$$I_{\text{O}} = I_{\text{rod}} + m(d/2)^2 = \tfrac{1}{12}Md^2 + \tfrac{1}{4}md^2 = \left(\frac{M + 3m}{12}\right)d^2$$

The total angular momentum of the system must be conserved:

$$L_1 = L_2 \;\Rightarrow\; \ell = I_{\text{O}}\omega \;\Rightarrow\; mv\cdot\frac{d}{2} = \left(\frac{M + 3m}{12}\right)d^2\cdot\omega$$

whence

$$\omega = \frac{6mv}{d(M + 3m)} = \frac{(6)(0.5)(12)}{(1.4)[2.2 + (3)(0.5)]} = 6.9498\ \text{rad/s} \approx 6.95\ \text{rad/s}$$ ☺

(b) Note that $I_{\text{O}} = \left(\frac{M + 3m}{12}\right)d^2 = \left[\frac{2.2 + (3)(0.5)}{12}\right](1.4)^2 = 0.60433\ \text{kg}\cdot\text{m}^2$

The initial energy is

$$K_1 = \tfrac{1}{2}mv^2 = \left(\tfrac{1}{2}\right)(0.5)(12)^2 = 36 \text{ J}$$

and the final energy is

$$K_2 = \tfrac{1}{2}I_O\omega^2 = \left(\tfrac{1}{2}\right)(0.60433)(6.9498)^2 = 14.594 \text{ J}$$

The fractional loss is

$$\text{loss} = \frac{K_1 - K_2}{K_1} = 1 - \frac{K_2}{K_1} = 1 - \frac{14.594}{36} \approx 0.595 \qquad ☺$$

That is, $\sim 59.5\%$ of the initial (kinetic) energy is lost.

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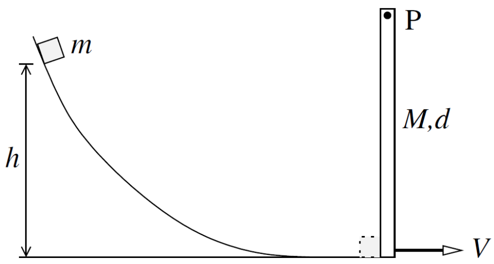
P8 [2011-2012 Spring - Final]: A small mass m slides from rest down a smooth slope, dropping a distance h in elevation. It strikes the end of a rod of length d and mass M and *sticks to it*. The rod is initially at rest and fastened by a pivot P. In terms of the given quantities, what is the speed V of the free end of the rod *just after the collision*? (The rotational inertia of the rod *about is center of mass* is $\frac{1}{12}Md^2$.)



SOLUTION: $I_{\text{com}} = \frac{1}{12}Md^2$

The speed of mass m *just before* the collision is found from an application of mechanical energy conservation:

$$mgh = \tfrac{1}{2}mv^2 \quad \Rightarrow \quad v = \sqrt{2gh}$$

The rotational inertia of the rod about P is obtained from the parallel-axis theorem:

$$I_P = I_{\text{com}} + Mh^2 = \tfrac{1}{12}Md^2 + M\left(\frac{d}{2}\right)^2 = \tfrac{1}{3}Md^2$$

With this, the rotational energy of the {rod+mass} system is found as

$$I_{\text{sys}} = I_P + md^2 = \tfrac{1}{3}Md^2 + md^2 = \left(\tfrac{1}{3}M + m\right)d^2$$

The speed V of the free end of the rod *just after* the collision follows from angular momentum conservation:

$$L_i = L_f \quad \Rightarrow \quad \ell_i = I_{\text{sys}}\omega \quad \Rightarrow mvd = \left(\tfrac{1}{3}M + m\right)d^2 \cdot \omega$$

Using $V = d\omega$, we have

$$mvd = \left(\tfrac{1}{3}M + m\right)d^2 \cdot \frac{V}{d} \;\Rightarrow\; 3m \cdot \sqrt{2gh} = (M + 3m)V \;\Rightarrow\; V = \frac{3m\sqrt{2gh}}{M + 3m}$$ ☺

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P9 [2013-2014 Spring - Final][E]: Write down the units of the following physical quantities in terms of kg, m, and s: (a) spring constant, (b) rotational inertia, (c) torque, and (d) angular momentum.

SOLUTION:

(a) $F = kx \;\Rightarrow\; k = \dfrac{F}{x} \;\Rightarrow\; [k] = \dfrac{\text{N}}{\text{m}} = \dfrac{\text{kg}\cdot\text{m}/\text{s}^2}{\text{m}} = \dfrac{\text{kg}}{\text{s}^2}$ ☺

(b) $I = mr^2 \;\Rightarrow\; [I] = \text{kg}\cdot\text{m}^2$ ☺

(c) $\vec{\tau} = \vec{r}\times\vec{F} \;\Rightarrow\; [\tau] = \text{m}\cdot\text{N} = \text{m}\cdot\dfrac{\text{kg}\cdot\text{m}}{\text{s}^2} = \dfrac{\text{kg}\cdot\text{m}^2}{\text{s}^2}$ ☺

(d) $\vec{\ell} = \vec{r}\times\vec{p} = m\vec{r}\times\vec{v} \;\Rightarrow\; [\ell] = \text{kg}\cdot\text{m}\cdot\dfrac{\text{m}}{\text{s}} = \dfrac{\text{kg}\cdot\text{m}^2}{\text{s}}$ ☺

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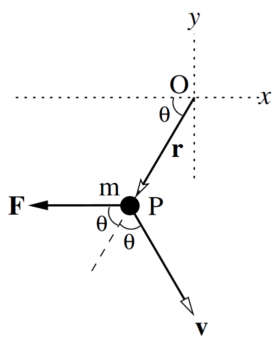
P10 [2013-2014 Spring - Final][E]: The figure shows an object of mass $m = 1.6$ kg moving on an *xy*-plane. At point P, the object has a velocity of magnitude $v = 4.1$ m/s and under the effect of a force of magnitude $F = 6.3$ N. If $r = 3.3$ m and $\theta = 60^\circ$, find (a) the torque acting on the object and (b) its angular momentum, both at point P and with respect to origin.



SOLUTION: $m = 1.6$ kg, $v = 4.1$ m/s, $F = 6.3$ N, $r = 3.3$ m, $\theta = 60^\circ$

(a) $\vec{\tau} = \vec{r}\times\vec{F} = rF\sin\theta\left(-\hat{\text{k}}\right) = (3.3)(6.3)\sin 60^\circ\left(-\hat{\text{k}}\right) \approx (18.0\ \text{N}\cdot\text{m})\left(-\hat{\text{k}}\right)$ ☺

(b) $\vec{\ell} = \vec{r}\times\vec{p} = \vec{r}\times m\vec{v} = mrv\sin\theta\,\hat{\text{k}} = (1.6)(3.3)(4.1)\sin 60^\circ\,\hat{\text{k}} \approx \left(18.7\ \text{kg}\cdot\text{m}^2/\text{s}\right)\hat{\text{k}}$ ☺

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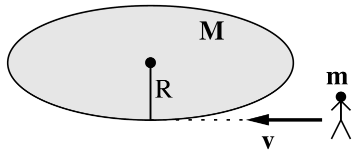
P11 [2013-2014 Spring - Final]: Your physics instructor, whose mass is $m = 74\ \text{kg}$, runs towards a merry-go-round with a speed $v = 2.8\ \text{m/s}$ and hops onto its rim and stays there, as shown in the figure. The merry-go-round is initially at rest and its mass and radius are respectively $M = 280\ \text{kg}$ and $R = 2.2\ \text{m}$. (a) What is the final angular speed of the {instructor + merry-go-round} system? (b) Calculate the initial and final kinetic energies of the {instructor + merry-go-round} system. (The rotational inertia of the merry-go-round is $\frac{1}{2}MR^2$.)



SOLUTION: $m = 74\ \text{kg}$, $v = 2.8\ \text{m/s}$, $M = 280\ \text{kg}$, $R = 2.2\ \text{m}$, $I_M = \frac{1}{2}MR^2$

(a) Since there is on external torque acting on the system, its total angular momentum must be conserved:

$$L_\text{i} = L_\text{f} \;\Rightarrow\; \ell_m = I_\text{sys}\omega_\text{f} \;\Rightarrow\; mRv = \left(I_M + mR^2\right)\omega_\text{f} = \left(\tfrac{1}{2}MR^2 + mR^2\right)\omega_\text{f} = \left(\tfrac{1}{2}M + m\right)R^2\omega_\text{f}$$

$$\omega_\text{f} = \frac{mv}{\left(\frac{1}{2}M + m\right)R} = \frac{(74)(2.8)}{\left[\left(\frac{1}{2}\right)(280) + 74\right](2.2)} = 0.44010\ \text{rad/s} \approx 0.440\ \text{rad/s} \quad ☺$$

(b) $K_\text{i} = \frac{1}{2}mv^2 = \left(\frac{1}{2}\right)(74)(2.8)^2 \approx 290\ \text{J}$ ☺

$$K_\text{f} = \tfrac{1}{2}I_\text{sys}\omega_\text{f}^2 = \tfrac{1}{2}I_\text{sys}\omega_\text{f}^2 = \tfrac{1}{2}\cdot\left(\tfrac{1}{2}MR^2 + mR^2\right)\cdot\omega_\text{f}^2 = \tfrac{1}{2}\left(\tfrac{1}{2}M + m\right)R^2\omega_\text{f}^2$$

$$\Rightarrow\; K_\text{f} = \left(\tfrac{1}{2}\right)\left[\left(\tfrac{1}{2}\right)(280) + 74\right](2.2)^2(0.44010)^2 \approx 100\ \text{J} \quad ☺$$

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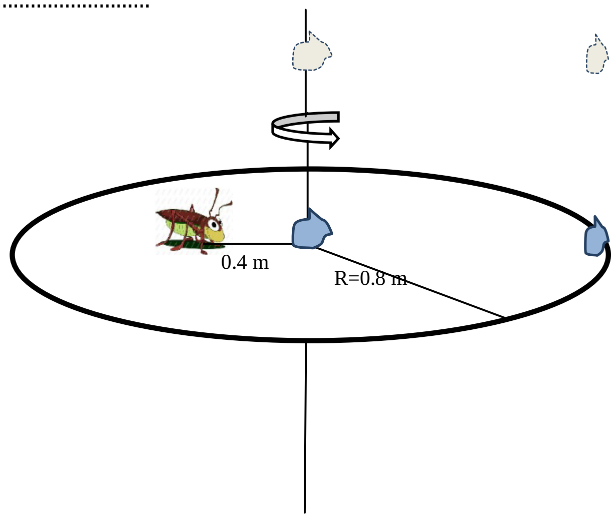
P12 [2014-2015 Fall - Final]: A cockroach of mass 0.01 kg is a distance 0.4 m away from the center of a horizontal disk of radius 0.8 m. The disk rotates freely about a vertical axis through its center with an angular speed of $2.4\ \text{rad/s}$. The rotational inertia of the disk is $320\times10^{-4}\ \text{kg}\cdot\text{m}^2$. Two wads of wet putty drop *vertically* on the disk from above; one with mass 0.05 kg sticks to the center and the other with mass 0.02 kg sticks to the rim of the disk. Treat the cockroach and the wads as particles. (a) What is the rotational inertia of the disk-cockroach-putties system? (b) What is the angular speed of the disk immediately after the wads of wet putty stick to it?



SOLUTION: $m_\text{c} = 0.01\ \text{kg}$, $m_1 = 0.05\ \text{kg}$, $m_2 = 0.02\ \text{kg}$, $d_\text{c} = 0.4\ \text{m}$, $R = 0.8\ \text{m}$,
$\omega_\text{i} = 2.4\ \text{rad/s}$, $I_\text{disk} = 320\times10^{-4}\ \text{kg}\cdot\text{m}^2 = 0.032\ \text{kg}\cdot\text{m}^2$

(a) Noting that wad m_1 does not contribute to the rotational inertia of the system (for its distance to the rotational axis is zero), we write the desired (final) rotational inertia of the disk-cockroach-putties system as

$$I_f = I_{disk} + m_c d_c^2 + m_2 R^2 = 0.032 + (0.01)(0.4)^2 + (0.02)(0.8)^2 = 0.0464 \text{ kg} \cdot \text{m}^2$$ ☺

In the following we shall need the initial rotational inertia of the disk-cockroach system:

$$I_i = I_{disk} + m_c d_c^2 = 0.032 + (0.01)(0.4)^2 = 0.0336 \text{ kg} \cdot \text{m}^2$$

(b) The required final angular speed is found from the principle of angular momentum conservation:

$$I_i \omega_i = I_f \omega_f \quad \Rightarrow \quad \omega_f = \frac{I_i}{I_f}\omega_i = \frac{0.0336}{0.0464}(2.4)$$

$$\Rightarrow \quad \omega_f \approx 1.74 \text{ rad/s}$$ ☺

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