Physics 1205 – Fall 2008 Final
December 18, 2008

Name (Print): Key

My signature below is a statement that all work contained in this exam is my own work. I have not copied work from any other source, or used any material other than one 3 by 5 card and my calculator.

Name (Signature):______________________________

DO NOT TURN THIS PAGE OVER UNTIL YOU ARE INSTRUCTED TO DO SO.

STOP WORKING ON THIS EXAM AS SOON AS YOU ARE INSTRUCTED TO DO SO.

You will have approximately 2 and a half hours to do this exam

- The following exam consists of 16 multiple-choice questions and 4 worked problems.
  - Point values are assigned to each problem in the exam.
- It is a good idea to first skim through the entire test and begin with the problems that seem most familiar. If you get stuck on a problem, skip to another.
- For the computational problems, please show all problem solving steps and all your work.
  - All work must be done on the pages provided.
  - Please write neatly and put a $\boxed{\text{BOX}}$ around your final answer.
  - Use significant figures in your answers.
- Calculators may be used only to do arithmetic. You cannot use your calculator for solving algebraic equations, for graphing, for vectors, etc.
- Moments of Inertia you may need. All of these are for rotation about the center of mass.
  Hoop: MR^2 Solid Sphere: $(2/5)MR^2$ Hollow Sphere: $(2/3)MR^2$
  Disk: $(1/2)MR^2$ Rod: $(1/12)ML^2$

Problem #	Max Points	Score	Problem #	Max Points	Score
1	5		12	5	
2	5		13	5	
3	5		14	5	
4	5		15	5	
5	5		16	5	
6	5		17	30	
7	5		18	30	
8	5		19	30	
9	5		20	30	
10	5				
11	5		Total	200	

I have really enjoyed being your professor this semester. Thanks for all of your hard work. I look forward to seeing you around the physics department in the next few years. Best wishes to you in the future. Have a great Holiday Season!

-Dr. Mike Strauss

Choose the one best answer for each of the multiple choice questions.

1. Two stones are dropped down two different wells. The first stone takes three times as long to reach the bottom of the first well as the second stone does to reach the bottom of the second well. Neglecting air resistance, if the second well has a depth *d*, what is the depth of the first well?

Same: $V_i = 0$, $a = g$

Want: d

Know: $t_1 = 3t_2$

$d = V_0 t - \frac{1}{2} g t^2 = -\frac{1}{2} g t^2$

$\frac{d_1}{d_2} = \frac{t_1^2}{t_2^2} = 9$

☐ $\sqrt{3}\,d$

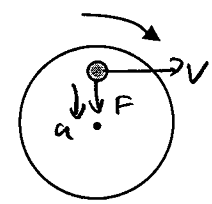
☐ $3d$

☒ $9d$

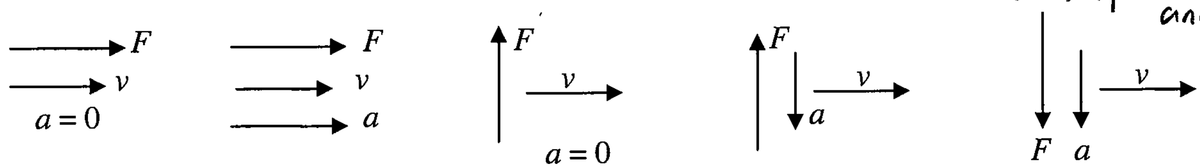
☐ $2d$

☐ $6d$

2. You put a penny on a circular turntable and watch it rotate clockwise at a constant speed as illustrated in the diagram. While it is rotating you think about all of the various vectors associated with this motion. Which of the sets of vectors below best describes the velocity, acceleration, and net force acting on the cylinder at the point indicated in the diagram?



centripetal a and f



☐ ☐ ☐ ☐ ☒

3. In a CD player, a laser beam reads the information off of the disk as the disk rotates. As the laser beam moves across the disk, the *tangential* velocity of the disk just below the laser beam always stays the same. (This is different from a record player where the angular velocity always stays the same, like 33.3 revolutions/minute). If the angular velocity of the disk is ω when the laser beam is at the outside edge of the disk, what is the angular velocity of the disk when the laser beam is halfway between the outside edge of the disk and the axis of rotation?

Same V_T

Want ω

Know; $r_2 = \frac{1}{2} r_1$

☒ 2ω

☐ $\omega/2$

☐ $\sqrt{2}\,\omega$

☐ 4ω

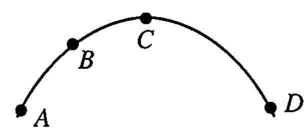
☐ $\omega/4$

$V = \omega r$

$\omega = V/r$

$\frac{\omega_2}{\omega_1} = \frac{V/r_2}{V/r_1} = \frac{r_1}{r_2}$ 2

4. Consider an object that is thrown near the surface of the earth and follows the trajectory shown in the figure. Which of the following statement is true?



- [ ] The velocity at point C is zero.
- [ ] The acceleration at point C is zero.
- [ ] The acceleration points up at point A and down at point D.
- [ ] The velocity at point C is the same as the velocity at point B.
- [x] None of the above are true.

5. On an air hockey table (with no friction) a puck is given a push with a constant force over a certain distance. If a puck with twice the mass is give a push with the same constant force over the same distance, which of the following is true?

Kinetic Energy is Same Since $K_f = W = Fd$

- [ ] Both pucks have the same momentum.
- [ ] The heavier puck has 1/2 the momentum of the lighter puck.
- [ ] The heavier puck has 2 times the momentum of the lighter puck.
- [ ] The heavier puck has $1/\sqrt{2}$ the momentum of the lighter puck.
- [x] The heavier puck has $\sqrt{2}$ times the momentum of the lighter puck.

$$\frac{p^2}{2m} = k$$

$$p = \sqrt{2km}$$

if m is double, p is greater by $\sqrt{2}$

6. A small car is stalled on the railroad tracks and is crushed by an oncoming train. During the collision

- [ ] the train exerts a force on the car, but the car does not exert a force on the train.
- [ ] the train exerts a greater amount of force on the car than the car exerts on the train.
- [ ] the car exerts a greater amount of force on the train than the train exerts on the car.
- [x] the train exerts the same amount of force on the car as the car exerts on the train.
- [ ] neither exerts a force on the other. The car gets crushed because it is in the way of the train.

7. A planet with twice the mass of Earth is orbiting a star that has twice the mass of the Sun at a distance that is twice the distance from the Sun to the Earth. If y is one year on earth, how long does it take the other planet to orbit its star?

- [x] $2y$
- [ ] $\sqrt{2}\,y$
- [ ] y
- [ ] $4y$
- [ ] $2\sqrt{2}\,y$
- [ ] $y/2$

$$v = \frac{2\pi r}{T}$$

$$\Sigma F = ma$$

$$\frac{G m_s m}{r^2} = \frac{m v^2}{r}$$

$$\frac{G m_s}{r^2} = \frac{4\pi^2 r^2}{T^2 r}$$

$$T = \left(\frac{4\pi^2 r^3}{G m_s}\right)^{1/2} \quad ①$$

Using ①

$$\frac{T_2}{T_1} = \left[\frac{\dfrac{4\pi^2 (2r_e)^3}{G(2m_s)}}{\dfrac{4\pi^2 r_e^3}{G m_s}}\right]^{1/2} = \sqrt{4} = 2$$

2

8. A baseball is pitched horizontally toward home plate with a velocity of 70 mph. Consider three different scenarios:

   I. The catcher catches the ball.
   II. The baseball is popped straight up at a speed of 70 mph.
   III. The baseball is hit straight back to the pitcher at a speed of 70 mph.

   Which of these scenarios exerts the greatest impulse on the ball?

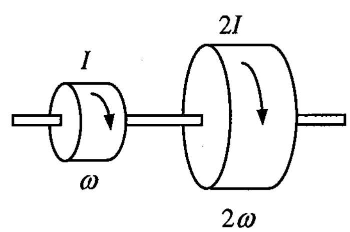
   - [ ] I
   - [ ] II
   - [x] III
   - [ ] Both II and III
   - [ ] All are the same.
   - [ ] It is impossible to know without knowing the amount of time the collision took.

   $\vec{I} = \Delta\vec{p}$

9. When the wind blows across the top of a chimney, the air in the chimney can howl as it vibrates at the resonant frequency of the chimney. If glass doors are closed at the bottom of the chimney, then the chimney can be considered as a pipe that is open at the top and closed at the bottom. Which of the following is true regarding displacement nodes and antinodes in the chimney?

   - [ ] There is a node at both the top and bottom of the chimney.
   - [ ] There is an anti-node at both the top and bottom of the chimney.
   - [ ] There is a node at the top of the chimney and an anti-node at the bottom of the chimney.
   - [x] There is an anti-node at the top of the chimney and a node at the bottom of the chimney.
   - [ ] There is a squirrel stuck in the chimney.

10. Two disks are mounted on low-friction bearings on a common shaft. The first disk has a rotational inertia I and is spinning with angular velocity ω. The second disk has rotational inertia $2I$ and is spinning in the same direction as the first disk with angular velocity 2ω. The two disks are slowly forced toward each other along the shaft until they couple and have a final common angular velocity. When they reach that common angular velocity, what is the kinetic energy of the system?



   - [ ] $(8/3)I\omega^2$
   - [ ] $(9/2)I\omega^2$
   - [ ] $(15/6)I\omega^2$
   - [ ] $(21/3)I\omega^2$
   - [ ] $(1/2)I\omega^2$
   - [x] $(25/6)I\omega^2$

Use Cons of L

$I\omega + 2I(2\omega) = I'\omega' = 3I\omega'$

$\omega' = \frac{5}{3}\omega$

So $K = \frac{1}{2} I' \omega'^2$

$= \frac{1}{2}(3I)\left(\frac{5}{3}\omega\right)^2$

$= \frac{25}{6} I\omega^2$

11. An object attached to an ideal spring oscillates back and forth with a maximum amplitude of $x_{max} = A$. When the object is at the point $x = A/2$, what percentage of the total energy of the oscillator is kinetic energy?

PE is $\frac{\frac{1}{2}kx^2}{\frac{1}{2}kA^2} = \frac{\left(\frac{A}{2}\right)^2}{A^2} = \frac{1}{4}$

- ☐ 0%
- ☐ 25%
- ☐ 50%
- ☒ 75%
- ☐ 100%

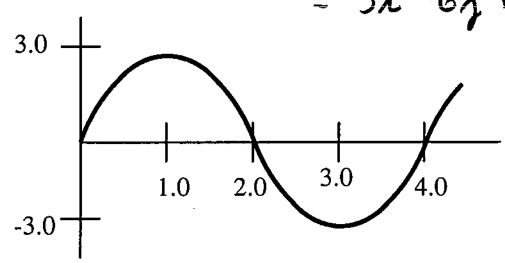
so KE is 3/4 or 75%

12. If a force **F** = (2.0 N)**i** + (3.0 N)**j** + (4.0 N)**k** is applied at a point (5.0 m)**i** + (6.0 m)**j** + (7.0 m)**k**, what is the torque around the origin (in N·m)?

- ☐ 45**i** + 34**j** + 27**k**
- ☐ 7**i** + 9**j** + 11**k**
- ☐ 10**i** + 18**j** + 28**k**
- ☐ 10**i** – 18**j** + 28**k**
- ☐ –3**i** – 6**j** – 3**k**
- ☒ 3**i** – 6**j** + 3**k**

$$\vec{\tau} = \vec{r} \times \vec{F} = (24-21)\hat{i} - (20-14)\hat{j} + (15-12)\hat{k} = 3\hat{i} - 6\hat{j} + 3\hat{k}$$

13. The graph shows a wave traveling to the right with a velocity of 2.0 m/s. The equation that best represents this wave is



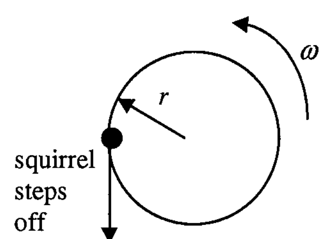
- ☐ $y = 6 \sin(\pi x/2 + \pi t)$
- ☐ $y = 6 \sin(2\pi x - 4\pi t)$
- ☐ $y = 3 \sin(2\pi x - 4\pi t)$
- ☐ $y = 3 \sin(\pi x - 2\pi t)$
- ☒ $y = 3 \sin(\pi x/2 - \pi t)$
- ☐ $y = 3 \sin(\pi x/2 + \pi t)$

$k = \frac{2\pi}{\lambda} = \frac{2\pi}{4} = \frac{\pi}{2}$

$\omega = 2\pi f = \frac{2\pi v}{\lambda} = \frac{2\pi 2}{4} = \pi$

$A = 3$

14. A squirrel (shown in the figure as the large dot) is standing at the edge of a merry-go-round with radius r, and the two are spinning at an angular velocity of ω in the direction shown in the figure. The squirrel steps off moving at a velocity, $v = \omega r$, along a line tangent to the motion of the outer rim of the merry-go-round as shown. After the squirrel steps off



$L_i = L_f$

$I_s \omega_s + I_m \omega_m =$

$r_s m_s v_s + I_m \omega$

- ☐ the angular velocity of the merry-go-round will decrease.
- ☐ the angular velocity of the merry-go-round will increase.
- ☒ the angular velocity of the merry-go-round will not change.
- ☐ the angular velocity of the merry-go-round may increase or decrease, depending on the exact moment of inertia of the merry-go-round.

since $I_s = m_s r_s^2$

and $\omega_s = v_s / r_s$

then $r_s m_s v_s + I_m \omega_m = r_s m_s v_s + I_m \omega'$

$\Rightarrow \omega = \omega'$

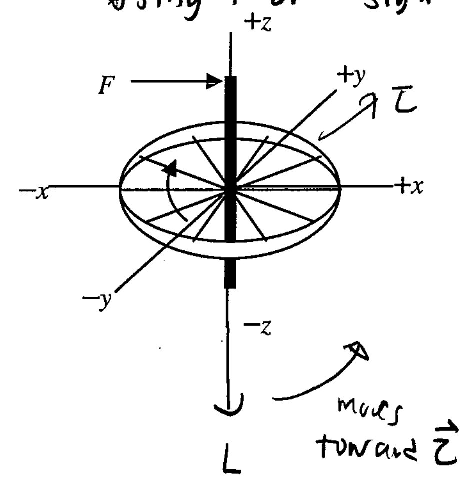
15. You and a friend have identical whistles that blow at a single frequency. Your friend gets in a car and drives first toward you at a certain speed, and then away from you at the same speed while both of you are blowing your whistles. Which of the following would be most likely?

- ☐ You hear sound beats when the friend is driving away from you but not when he is driving toward you.
- ☐ You hear sound beats when the friend is driving toward you but not when he is driving away from you.
- ☒ You hear sound beats when the friend is driving away from you and toward you, and the beat frequency in the two cases is nearly the same.
- ☐ You hear sound beats when the friend is driving away from you and toward you, but the beat frequency in the two cases is quite different.
- ☐ You do not hear sound beats in either case.

$f_b = |f - f'|$ $\qquad f' = \frac{v}{v \pm v_s}$

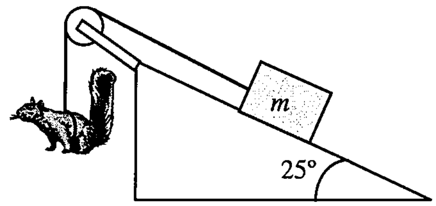
for $v_s < v$ f_b is about the same using + or - sign

16. A wheel is spinning in the x-y plane. Looking down from the $+z$ axis the wheel spins clockwise as shown in the figure. If a force F is exerted on the axle of the wheel in the $+x$ direction at a point on the $+z$ axis as shown, which direction will the point where the force is exerted tend to move?



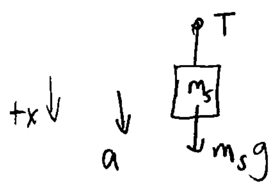
☐ $+x$	☐ $-x$
☐ $+y$	☒ $-y$
☐ $+z$	☐ $-z$

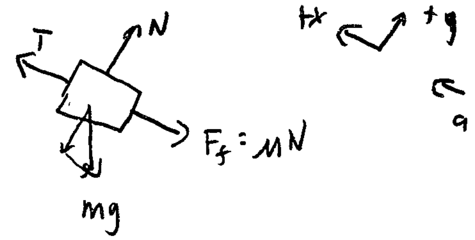
17. A squirrel with a mass of 1.11 kg is connected to a block (m = .500 kg) by a massless rope draped over a pulley as shown. The rope runs parallel to the ramp then hangs from the pulley. The coefficient of kinetic friction between the block and the ramp is 0.233. You may assume the pulley has no mass or friction. When the squirrel is released from rest



(a) What is the tension in the rope?
(b) What is the acceleration of the squirrel?
(c) How far will the squirrel fall in 1.20 seconds?

a) Draw FBD





$\Sigma F = m_s a$

$-T + m_s g = m_s a$

① $a = g - T/m_s$

$\Sigma F_x = ma$

$T - mg\sin\theta - \mu N = ma$

② $T - mg\sin\theta - \mu mg\cos\theta = ma$

$\Sigma F_y = 0$

$N = mg\cos\theta$

Plug ① in ② $T - mg\sin\theta - \mu mg\cos\theta = mg - Tm/m_s$

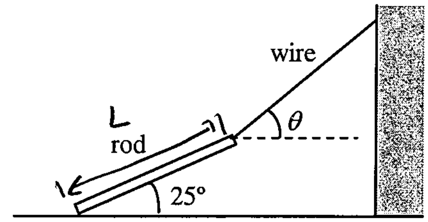
$T(1 + m/m_s) = mg(1 + \sin\theta + \mu\cos\theta)$

$$T = \frac{mg(1+\sin\theta+\mu\cos\theta)}{1+m/m_s} = \frac{(.50)(9.8)(1+\sin 25 + .233\cos 25)}{1+.50/1.11} = \boxed{5.52\text{ N}}$$

b) from ① $a = g - T/m_s = 9.8 - \frac{5.52\text{ N}}{1.11\text{ kg}} = \boxed{4.83\text{ m/s}^2}$

c) $y - y_0 = v_0 t - \frac{1}{2}at^2 = \frac{1}{2}(4.83\text{ m/s}^2)(1.20\text{s}) = \boxed{3.48\text{ m}}$

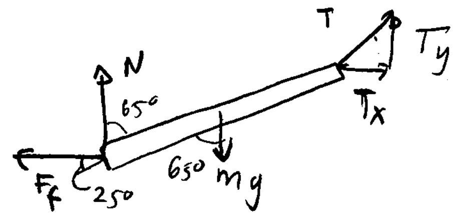
18. A thin uniform steel rod with a mass of 75 kg is held in an inclined position by a support wire as shown in the figure. The coefficient of static friction between the rod and the horizontal surface is 0.65. The rod is just on the verge of slipping to the right.



(a) Find the tension in the support wire and the angle the wire makes with the horizontal direction, θ. (Hint: the point involving the most unknown forces is at the top of the rod.)

(b) A wind blows and sets the wire vibrating. If the wire is 2.0 meters long and has a mass of 0.35 kg, what is the fundamental frequency of the wire? (You can assume that the two ends of the wires are nodes.)

a) Draw FBD of rod



Take torque around top point

$\Sigma \tau = 0$

$$-mg\frac{L}{2}\sin 65^\circ + NL\sin 65^\circ + F_f L \sin 25^\circ = 0 \qquad F_f = \mu N$$

$$-\frac{mg\sin 65}{2} + N(\sin 65^\circ + \mu \sin 25^\circ) = 0$$

$$N = \frac{mg\sin 65^\circ}{2(\sin 65^\circ + \mu \sin 25^\circ)} = 282\ N$$

In x: $\Sigma F_x = 0 \qquad T_x = F_f = \mu N$

$T_x = (.65)(282\ N) = 183\ N$

In y: $\Sigma F_y = 0$

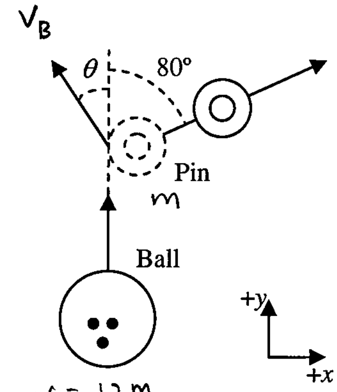
$T_y + N - mg = 0$

$T_y = mg - N = 453\ N$

$$T = \sqrt{T_x^2 + T_y^2} = \boxed{489\ N} \qquad \theta = \tan^{-1}\frac{T_y}{T_x} = \boxed{68^\circ}$$

b) $$f = \frac{v}{\lambda} = \frac{\sqrt{\frac{T}{\mu}}}{2L} = \frac{\sqrt{\frac{489\ N}{.35\ kg/2.0\ m}}}{(2)(2\ m)} = \boxed{13\ Hz}$$

19. In order to convert a tough split in bowling it is necessary to strike the pin a glancing blow as shown. Assume that the bowling ball has a mass five times the mass of the pin, and is initially traveling at 12.0 m/s along the +*y* axis. After the collision, the pin goes off at an angle of 80° from the original direction of the ball, as shown. Assume that the collision is elastic and ignore any spin of the ball.
(a) Calculate the speed of the pin and the speed of the ball right after the collision.
(b) Calculate the angle through which the bowling ball was deflected, *θ*.



$V = 12\,m/s$
$m_B = 5m$

Cons of p in y:

$$m_B V = m_B V_{By} + m V_p \cos 80$$
$$5mV = 5mV_{By} + mV_p \cos 80$$
① $$5V = 5V_{By} + V_p \cos 80$$

Cons of p in x:

$$0 = -m_B V_{Bx} + m V_p \sin 80$$
$$0 = -5m V_{Bx} + m V_p \sin 80$$
$$5V_{Bx} = V_p \sin 80 \quad ②$$

Cons of kinetic energy (elastic)

$$\tfrac{1}{2} m_B V^2 = \tfrac{1}{2} m_B V_B^2 + \tfrac{1}{2} m V_p^2$$
$$5mV^2 = 5mV_B^2 + mV_p^2$$
③ $$5V^2 = 5(V_{Bx}^2 + V_{By}^2) + V_p^2$$

I now have 3 equations and 3 unknowns (V_{Bx}, V_{By}, V_p)

Solve ① for V_{By}: $V_{By} = \dfrac{-V_p \cos 80}{5} + V$ ④

Solve ② for V_{Bx}: $V_{Bx} = \dfrac{V_p \sin 80}{5}$ ⑤

Plug ④ + ⑤ in ③

$$5V^2 = 5\frac{V_p^2 \sin^2 80}{25} + 5\frac{V_p^2 \cos^2 80}{25} + 5V^2 - \frac{10 V_p V \cos 80}{5} + V_p^2$$

solve for V_p: $$V_p^2\left(\frac{\sin^2 80}{5} + \frac{\cos^2 80}{5} + 1\right) = 2 V_p V \cos 80$$

$$V_p = \frac{10 V \cos 80}{(\underbrace{\sin^2 80 + \cos^2 80}_{1} + 5)} = \frac{(10)(12\,m/s)(\cos 80)}{6} = \boxed{3.47\,m/s}$$

$$V_B = \sqrt{V_{Bx}^2 + V_{By}^2} = \boxed{11.9\,m/s}$$

From ④ $V_{By} = 11.9\,m/s$

From ⑤ $V_{Bx} = .683\,m/s$

(b) $\theta = \tan^{-1}\dfrac{V_{Bx}}{V_{By}}$

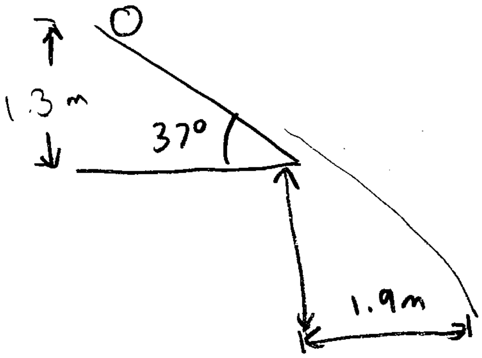
$= \boxed{3.2^\circ}$

20. While trying to hang Christmas decorations on top of your roof, you accidentally drop a hollow spherical glass ornament. The ornament starts from rest and rolls, without slipping, down the roof a vertical distance of 1.3 meters. The roof is pitched at an angle of 37 degrees above the horizontal. When the ornament gets to the bottom of the roof, it flies through the air and hits a squirrel which is standing a horizontal distance of 1.9 m from the edge of the roof and is foraging for nuts on the ground. How high is the bottom of the roof above the ground?

(You must solve this problem using the Context-Rich Problem work sheets starting on the next page. Partial credit will be given on this problem for steps performed correctly. For this problem, once a significant mistake is made no more credit will be given for any part of the problem, even if it is done correctly.)

FOCUS the PROBLEM

Draw a Picture Using ALL Given Information



Questions(s) How high is the bottom of the roof

Approach Use cons of mechanical energy (with rolling) to get the speed of the ornament as it leaves the roof. Use Kinematic equations (projectile motion) to get the height

DESCRIBE the PHYSICS

Diagram(s) and Define Quantities

Before | Energy Transfer | After

$y_1 = 1.3\,m$
$v_1 = 0$

(none)

$y_2 = 0$
$v_2 = ?$
$\omega = v_2 R$

Projectile motion

$V_{2x} = V_2 \cos\theta$
$V_{2y} = -V_2 \sin\theta$
$x_2 = 0$
$y_2 = ?$
$a_x = 0$
$a_y = -g$
$t_2 = 0$

$V_{3x} = V_{2x}$
$V_{3y} = ?$
$x_3 = 1.9\,m$
$y_3 = 0$
$t_3 = ?$

$\theta = 37°$

Target Quantity(ies)

$\boxed{y_2}$

Quantitative Relationships

$y_2 - y_1 = v_{1y}(t_2 - t_1) + \frac{1}{2}a(t^2 - t_1)^2$

$V = \omega R$

$E_i = E_f$ $\quad E = U_g + K$

$U_g = mgh$ $\quad K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

PLAN the SOLUTION

Construct Specific Equations (Same Number as Unknowns)

Find y_2:

$$y_3 - y_2 = V_{2y}(t_3 - t_2) + \frac{1}{2}a_y(t_3 - t_2)^2$$

① $-y_2 = -V_2 \sin 37^\circ t_3 - \frac{1}{2} g t_3^2$ $\boxed{t_3, y_2, V_2}$

Find t_3 using x direction

$$V_{2x} = \frac{x_3 - x_2}{t_3 - t_2}$$

② $t_3 = \dfrac{x_3}{V_2 \cos\theta}$

Find V_2 using cons of energy

$$K_i + U_i = K_f + U_f$$

$$0 + mgy_1 = \frac{1}{2}mV_2^2 + \frac{1}{2}I\omega_2^2 + 0$$

$$mgy_1 = \frac{1}{2}mV_2^2 + \frac{1}{2}\left(\frac{2}{3}MR^2\right)\frac{V_2^2}{R^2}$$

$$gy_1 = V_2^2\left(\frac{1}{2} + \frac{1}{3}\right) = V_2^2 \frac{5}{6}$$

③ $V_2 = \sqrt{\frac{6}{5} g y_1}$

To make easier, Find values for ② and ③ and plug those into ①

③ $V_2 = \left(\frac{6}{5}(9.8\,m/s^2)(1.3\,m)\right)^{1/2} = 3.91\,m/s$

② $t_3 = \dfrac{1.9\,m}{(3.91\,m/s)(\cos 37^\circ)} = .608\,s$

Check Units

③ $\left(\frac{L}{(T)^2}(L)\right)^{1/2} = \frac{(L)}{T}$

② $\frac{(L)}{(L)/(T)} = (T)$

EXECUTE the PLAN

Calculate Target Quantity(ies)

$$y_2 = t_3 V_2 \sin 37^\circ + \frac{1}{2} g t_3^2$$

$$= (.608\,s)(3.91\,m/s)\sin 37^\circ + \frac{1}{2}(9.8\,m/s^2)(.608\,s)^2$$

$$= \boxed{3.2\,m}$$

EVALUATE the ANSWER

Is Answer Properly Stated?

Yes, in m

Is Answer Unreasonable?

No ~ 11 feet

Is Answer Complete?

Yes

(extra space if needed)