Name: ________________________________

Place an X next to your Problems Lab section:

___ Lowhorn (TR 8:00 – 10:30)       ___ Lowhorn (TR 5:40 – 8:10)
___ Weller (TR 11:20 – 1:50)        ___ Gritton (WF 8:00 – 10:30)
___ Gritton (TR 2:40 – 5:10)        ___ Smith (WF 11:30 – 2:00)

The following test consists of two parts. Part I contains 10 multiple choice questions worth 3 points each. Write the letter of the best answer in the boxes provided at the end of the section. Part II contains 3 problems worth a total of 70 points.

There is no partial credit for the multiple choice questions. To receive full credit on the problems, all reasoning must be shown (using symbols!) and your answer must have the appropriate units.

Start by writing down basic definitions or equations that you are using in your solution. Be sure to show your set-up.

Keep numbers out of your equations until as late as possible in your solutions. Box-in your final answers.

Be careful, be concise, but be complete.

Ask if you don’t understand the statement of a given problem.

Please silence and put away your cell phones, and turn any ball caps backwards.

You have 1 hour and 25 minutes to complete this exam.

Budget your time accordingly!

Instructor use only:

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Part I – Multiple Choice (3 points each)

Choose the best answer to each of the following questions.

1. In a completely elastic collision, which of the following is true?
   A. Momentum is conserved.  B. Kinetic energy is conserved.  C. Kinetic energy is not conserved.
   D. Both A and B.  E. Both A and C.

2. A torque of 70 N m is required to open the door of a bank vault. What magnitude of force, $F$, is required to open the vault door, if it is applied as shown in the diagram?

   ![Diagram](Hinge 1.5 m F 40°)

   A. 73 N  B. 12 N  C. 110 N  D. 560 N  E. 240 N

3. Which of the following is not one of the angular kinematic equations?
   A. $\tau = \theta_i + \theta_f t^2 - \omega_f$  B. $\theta_f = \theta_i + \omega_i t + \frac{1}{2} \alpha t^2$  C. $\theta_f = \theta_i + \frac{1}{2}(\omega_i + \omega_f) t$
   D. $\omega_f = \omega_i + \alpha t$
   E. $\omega_f^2 = \omega_i^2 + 2\alpha(\theta_f - \theta_i)$

4. The quantity “x” in linear kinematics corresponds to _______ in angular kinematics.
   A. $\omega$  B. $t$  C. $\alpha$  D. $\theta$  E. $\tau$

5. You are pulling a box along rough, horizontal ground, by means of a rope attached to the box at an angle of 25° above the horizontal. You pull with a force of 72 N, and move the box a distance of 5.0 m in 7.5 s. How much work did you do in pulling the box?

6. In the previous question, what power did you expend while pulling the box?
   A. 43 W  B. 96 W  C. -211 W  D. 184 W  E. -5 W

7. The work done by friction
   A. is always positive.
   B. is always negative.
   C. can be positive or negative, depending on the specific situation.
   D. always points in the direction opposite to that of the motion of the object.
   E. always points in the same direction as that of the motion of the object.

8. A tire moves through an angular distance of 39.3 radians. How many revolutions does the tire make?
   A. 23 revolutions  B. 1.6 revolutions  C. 6.3 revolutions  D. 17 revolutions  E. 31 revolutions
9. A pendulum consisting of a ball of mass \( m = 42 \text{ g} \) attached to the end of a piece of string has a gravitational potential energy of 0.016 J (relative to \( y = 0 \)) at its highest position. What is the ball’s speed as it swings through its lowest position (i.e., when the string is vertical)?

A. 0.87 m/s  B. 0.16 m/s  C. 7.7 m/s  D. 12.3 m/s  E. 2.4 m/s

10. The tire on a large earth-moving truck has a diameter of 4.0 m, and is spinning with angular velocity 3.8 rad/s. What is the tangential velocity of a point on the rim of the tire?

A. 95.1 m/s  B. 7.6 m/s  C. 19.5 m/s  D. 27.0 m/s  E. 0.3 m/s

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Write your multiple choice answers here. This is the ONLY place your answers will be graded!

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Part II – Long Answer Questions

1. (25 pts)
   It had to happen... someone has finally convinced the Myth Busters that the laws of conservation of energy and momentum might actually be myths! To test the laws, the Myth Busters crew are going to slide a large concrete block of mass $m_1 = 1600$ kg down a frictionless hill (height $H = 8.5$ m), let it collide with a second concrete block of mass $m_2 = 2300$ kg in a completely inelastic collision, and then measure how far the combined masses travel on flat, rough ground. To help the Myth Busters in their task, you are going to work through the physics for them. In the diagram, the surface from point A to C is frictionless; beyond point C, the coefficient of friction is $\mu = 0.3$. Block 1 starts from rest at the top of the hill, and the combined blocks stop at point D.

   (a) (5 pts) How fast was block 1 moving at point B, just before it collided with block 2? (Be sure to indicate, on the diagram above, where your $y = 0$ position is.)

   (b) (6 pts) How fast were the combined blocks moving immediately after the collision?

   (c) (7 pts) How much work did the friction force do on the combined blocks as they moved from C to D?

   (d) (7 pts) What is the distance from C to D that the combined blocks moved before coming to a stop?
2. (20 pts) James Bond finds himself in another precarious situation—hanging from a horizontal beam, above a pool full of vicious, man-eating sharks. The beam has a length \( L = 6.0 \, \text{m} \) and weighs 150 N. At its left end, the beam is supported by a hinge, and at the right by a vertical rope. The breaking strength of the rope is 700 N (that is, if the tension in the rope exceeds 700 N, it will snap). James Bond has a mass of 85 kg.

(a) (10 pts) What is the maximum distance \( x \) that Bond can move along the beam, without breaking the rope? (Draw your extended FBD in the space beside the diagram.)

(b) (8 pts) What is the y-component \( F_{Hy} \) of the force from the hinge on the beam, when Bond is at the distance you found in (a)?

(c) (2 pts) What is the x-component \( F_{Hx} \) of the force from the hinge on the beam, when Bond is at the distance you found in (a)? (Show your reasoning!)
3. (25 pts) A vinyl record starts spinning from rest, taking 4.0 s to reach its final angular velocity of 33 rpm (revolutions per minute). The radius of the record is 15 cm.

(a) (3 pts) Convert 33 rpm to radians per second.

(b) (6 pts) What is the angular acceleration of the record during the 4.0 s interval that it is speeding up?

(c) (7 pts) During this time, how many revolutions did the record make?

(d) (3 pts) A bug is sitting on the very outer edge of the record. What was the bug’s tangential acceleration during the 4.0 s interval?

(e) (6 pts) Consider now the bug sitting on the edge of the record while the record is spinning at a constant 33 rpm. In a time of 30 minutes, how far did the bug travel? (That is, find the linear distance, in meters, traveled by the bug.)
Equations

\[ x_f = x_i + v_{ix} t + \frac{1}{2} a_x t^2 \quad x_f = x_i + \frac{1}{2} (v_{ix} + v_{fx}) t \quad v_{fx} = v_{ix} + a_x t \quad v_{fx}^2 = v_{ix}^2 + 2a_x (x_f - x_i) \]

\[ f_x = \mu_k F_N \quad f_{s,\text{max}} = \mu_s F_N \quad F_{sp,x} = -k x \quad \sum F_c = m v^2 / r \quad s = \theta r \quad v = \omega r \quad a_i = \alpha r \]

\[ \ddot{p} = m \ddot{v} \quad KE = \frac{1}{2} mv^2 \quad KE = \frac{1}{2} I \omega^2 \quad PE = mg y \quad PE = \frac{1}{2} k x^2 \quad P = \frac{E}{t} = \frac{W}{t} \]

\[ W = F_x \Delta x \quad \sum \ddot{F} = \frac{\Delta p}{\Delta t} \quad I = \sum m r^2 \quad L = I \omega \quad \sum \ddot{I} = I \ddot{\alpha} \quad \tau = r_x F \]

\[ m = \rho V \quad p = p_{\text{top}} + \rho_{\text{liq}} gh \quad v_1 A_1 = v_2 A_2 \quad p_1 + \rho g y_1 + \frac{1}{2} \rho v_1^2 = p_2 + \rho g y_2 + \frac{1}{2} \rho v_2^2 \]

\[ T_F = \frac{2}{3} T_C + 32 \quad T_K = T_C + 273 \quad \Delta L = \alpha L \Delta T \quad \Delta V = \beta V \Delta T \quad Q = mc \Delta T \quad Q = mL \]

\[ KE_{\text{ave}} = \frac{1}{2} k T \quad x(t) = x_{\text{max}} \cos(\omega t) \quad \omega_{\text{res}} = \sqrt{\frac{k}{m}} \quad \omega_{\text{res}} = \sqrt{\frac{g}{L}} \]

\[ y(x,t) = y_{\text{max}} \sin(kx \pm \omega t) \quad v = \frac{\omega}{k} = \lambda f \quad v = \sqrt{\frac{F_i}{\mu}} \quad v_{\text{air}} = \left(331 \frac{m}{s}\right) \sqrt{1 + \frac{T_C}{273}} \]

\[ f_n = \frac{n v}{2L} \quad (n = 1, 2, 3, \ldots) \quad f_n = \frac{nv}{4L} \quad (n = 1, 3, 5, \ldots) \]

Physical Constants

1 km = 0.621 mi \quad 1 N = 0.225 lb \quad N_A = 6.02 \times 10^{23} \quad R = 8.31 \frac{J}{\text{mol} \cdot \text{K}} \quad \rho_{\text{water}} = 1000 \frac{\text{kg}}{\text{m}^3}

\[ \rho_{\text{air}} = 1.29 \frac{\text{kg}}{\text{m}^3} \quad p_{\text{atm}} = 1 \text{ atm} = 1.01 \times 10^5 \text{ Pa} \quad v_{\text{air}} = \left(331 \frac{m}{s}\right) \sqrt{1 + \frac{T_C}{273}} \quad v_{\text{water}} = 1460 \frac{m}{s} \]

\[ c_{\text{water}} = 4186 \frac{J}{\text{kg} \cdot \text{C}^\circ} \quad c_{\text{aluminum}} = 900 \frac{J}{\text{kg} \cdot \text{C}^\circ} \quad L_{f,\text{water}} = 335,000 \frac{J}{\text{kg}} \]