Name: ________________________________

Place an X next to your Problems Lab section:

___ Smith (TR 1:00 – 3:30)  ___ Youngkins (WF 8:00 – 10:30)
___ Frank (WF 1:50 – 4:20)  ___ Weller (WF 11:05 – 1:35)

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.

Multiple Choice: There is no partial credit for the multiple choice questions. Choose the best answer from the choices provided. Your answers must be recorded in the spaces provided at the end of the multiple choice section.

The Problems: To receive full credit on the problems, all reasoning must be shown and any numerical answer must have the appropriate units. Box in your final answer.

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

Cell phones must be put in silent or vibrate mode and put away. Anybody caught using a cell phone during the test will receive a zero grade.

You may not leave the room during the exam unless you have permission from one of the proctors.

Cheating: Cheating in any form will not be tolerated, and will result in a zero grade for this test. Additionally, a formal complaint will be submitted to the Office of Judicial Affairs.

You should have only a pencil, eraser, calculator, and the test papers out – all other material should be put away.

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. Write your answers in the spaces provided at the end of the MC questions.

1. A ball rolls along the top of a table in a straight line with a constant speed of 2.2 m/s. Call the direction of motion of the ball the \( x \)-direction. The ball then rolls off the edge of the table. What is the \( x \)-component of the ball’s velocity just before it hits the floor?
   - A. 0 m/s
   - B. 9.8 m/s
   - C. 2.2 m/s
   - D. -9.8 m/s
   - E. *Not enough information is given to say.*

2. The frequency of the circular motion of a spinning compact disc in a CD player is 15 Hz. This means that
   - A. it takes 15 s for the CD to make one complete revolution.
   - B. the CD rotates 15 times each second.
   - C. the CD rotates 15 times each minute.
   - D. the CD has a speed of 15 m/s.
   - E. the CD has an acceleration of 15 m/s^2.

3. Dr. Smith has a mass of 80 kg. What is the magnitude of his weight if he is standing on an incline of 40°?
   - A. 784 N
   - B. 1300 N
   - C. 26 N
   - D. 601 N
   - E. 207 N

4. Dr. Smith has a mass of 80 kg. What is the magnitude of his *apparent weight* if he is standing on an incline of 40°?
   - A. 784 N
   - B. 1300 N
   - C. 26 N
   - D. 601 N
   - E. 207 N

5. If the acceleration of an object is zero, which of the following statements is true?
   - A. The object must be motionless.
   - B. There are no forces acting on the object.
   - C. The object could be moving in uniform circular motion.
   - D. The object must be in free fall.
   - E. The net force acting on the object is zero.

6. A heavy crate is resting on the ground (which is horizontal and fairly rough). It has a rope attached so that it may be pulled along the ground. Your job is to pull on the rope and move the crate. Keeping the rope horizontal, initially the crate doesn’t move, so you pull harder and harder until the crate eventually starts sliding with a constant velocity. When does the friction force acting between the crate and the ground have its largest value?
   - A. When the crate was at rest, and no tension was in the rope.
   - B. When the crate was moving at constant velocity.
   - C. When you were pulling hard enough on the rope such that the crate was just about to start moving.
   - D. During the time you were increasing the strength of your pulling.
   - E. There is no friction force acting on the crate at any time.

7. A cannon ball is fired to the right at an angle of 55° above the horizontal, with an initial speed of 35 m/s. If we take the \( x \) and \( y \) directions to be to the right and vertically upwards, what are the \( x \)- and \( y \)-components of the cannon ball’s velocity at the *highest* point in its motion? (Assume that air resistance is negligible.)
   - A. 20.1 m/s; -9.8 m/s
   - B. 0 m/s; 0 m/s
   - C. 20.1 m/s; 0 m/s
   - D. 9.8 m/s; -9.8 m/s
   - E. 0 m/s; -9.8 m/s
8. An object of mass $m$ moves clockwise around a circular path of radius $r$ with a constant speed $v$. At which point on the path does the object’s velocity point directly towards the left side of the page?

9. A certain force acts on a 5-kg object to produce an acceleration of $3 \text{ m/s}^2$. What is the resulting acceleration if the same force acts on a 7-kg object?
   A. 1.31 m/s$^2$
   B. 2.14 m/s$^2$
   C. 2.57 m/s$^2$
   D. 2.81 m/s$^2$
   E. 3.25 m/s$^2$

10. In an experiment in which position ($x$) and time ($t$) data was collected, the slope of a position vs time graph was determined to be 23.3286 m/s. The fractional uncertainties in position and time are $\text{FU}(x) = 0.02$ and $\text{FU}(t) = 0.06$. How should the slope be correctly reported in your lab notebook?
   A. $23.3286 \pm 0.06 \text{ m/s}$
   B. $23 \pm 1 \text{ m/s}$
   C. $23.33 \pm 0.06 \text{ m/s}$
   D. $23.33 \pm 0.02$
   E. $23.3 \pm 0.4 \text{ m/s}$

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) A box of mass 45 kg is being pulled up a rough incline of angle 34° at a constant speed by a spring, as shown in the diagram. The spring has a spring constant of 6300 N/m, and is stretched 5 cm beyond its equilibrium length. Take the positive x-direction to be up the incline, and the positive y-direction to be perpendicularly away from the incline surface, as shown.

(a) (6 pts) In the space next to the diagram, draw a good FBD for the box.

(b) (5 pts) What is the magnitude of the normal force acting on the box?

(c) (4 pts) What is the magnitude of the spring force acting on the box?

(d) (6 pts) What is the magnitude of the friction force acting on the box? (Hint: you can’t use \( f = \mu F_N \) to find the friction force here. You might think about Newton’s 2nd law, though…)

(e) (4 pts) What is the value of the coefficient of friction between the box and incline surface?
2. (25 pts) You’re still playing with your new tennis racket (the one you received for your birthday in Test 1). This time, you are trying to see how far you can hit a tennis ball. On one hit, you send the ball speeding away at 20.5 m/s at an angle of 42° above the horizontal. It hits the ground a few seconds later, having traveled a horizontal distance of 44 m. The ball was at an unknown height above ground level when it was hit.

(a) (6 pts) Draw a sketch of the problem. Be sure to include directions and the $x = 0$ and $y = 0$ positions. Next to your sketch make a list of the appropriate kinematic quantities for the $x$ and $y$ directions.

(b) (4 pts) How long did it take for the ball to hit the ground?

c) (5 pts) What was the height of the tennis ball when it was hit?

d) (4 pts) What was the tennis ball’s final $y$-component of velocity just before it hit the ground?

e) (6 pts) What was the ball’s final velocity just before it hit the ground?
3. (20 pts) *Totem tennis* is a game in which a tennis ball, attached to a vertical pole (the *totem* pole) by a length of string, is hit back and forth by players standing on either side of the pole. For this question, we’ll imagine that the tennis ball has been hit so that it undergoes *uniform circular motion* with a period of 1.14 s. The angle between the string and the pole is 75°, and the length of the string is 1.24 m. The tennis ball has a mass of 57 g.

(a) (3 pts) What is the radius of the tennis ball’s circular motion?

(b) (3 pts) What is the frequency of the tennis ball’s circular motion?

(c) (4 pts) What is the speed of the tennis ball?

(d) (10 pts) What is the magnitude of the tension force applied to the tennis ball by the string? (To be considered complete, your solution must include a FBD.)
Equations

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

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

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

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

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

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

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

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

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

Physical Constants

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

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

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