PHYSICS-2101 Fall Semester 2012
Examination 1
September 25, 2012

Instructor and section (circle yours)
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LSU ID ____________________

Name (print) ____________________

Signature ____________________

TURN OFF AND PUT AWAY ALL CELL PHONES, PAGERS, iPods, MP3s, OR ANY OTHER COMMUNICATIONS, AUDIO, OR VIDEO DEVICES

Have your LSU ID ready when you turn in your paper.

You may not use cell phone or smart phone application as your calculator.

You may use an ordinary scientific or even graphing type calculator, as long as it is not of the "full keyboard" sort.

Examine your paper to be sure it is complete and legible. There should be 3 problems and 3 questions, totaling 100 points. Examine your formula sheet as well. It should include only 2 pages.

For the multiple choice questions, clearly indicate your selected answer(s) for each of the part(s) of the question, circle the correct answers! For some questions there may be more than one correct response. If so, be sure mark each one. There is room on the paper for scratch work or calculations, but that work will not be checked or graded. There is no partial credit awarded for multiple choice questions.

For the problems, show your work in the space provided. Even a correct answer, without supporting work, will receive little or no credit. Partial credit may be awarded for problems if warranted.

Be sure that numerical answers appear with appropriate SI units. Points will be deducted for missing, incorrect, or "silly" units.

If the final answer is, in fact, a dimensionless quantity, please write the numerical result followed by the word "dimensionless."

If you need more room for your problem solution you may write on the back of the page, but be sure to add a note to look on the back. Otherwise anything on the back of the paper will be regarded as scratch work and will not be checked or graded.

You will have approximately 60 minutes to complete this examination.

Solutions will be posted to the course web page within a few days.
Problem #1 (18 points): Show your work.

You try to hit a small box on the floor with a marble of mass \( m = 0.2 \text{ kg} \) which is fired from a spring gun that is mounted on a table. The table is \( H = 0.8 \text{ m} \) high. The ball strikes the box with a speed \( v_i = 5 \text{ m/s} \). Assume there is no air resistance or friction.

\[ m = 0.2 \text{ kg}, \quad v_i = 5 \text{ m/s}, \quad H = 0.8 \text{ m} \]

(a) (6 points) What is the speed \( v_i \) of the ball when it leaves the spring gun?

\[ \frac{v_i^2}{2} \text{ (could be solved using horizontal projectile motion, too)} \]

\[ W = \Delta K \quad \text{where} \quad W = W_f - mg \Delta y = mgH, \quad \Delta y = -H \]

\[ \Delta K = K_f - K_i = \frac{m}{2} (v_f^2 - v_i^2) \]

\[ mgH = \frac{m}{2} (v_f^2 - v_i^2) \]

\[ v_i = \sqrt{\frac{v_f^2}{2} - 2gH} = \sqrt{(5\frac{m}{s})^2 - 2(9.8\frac{m}{s^2})(0.8\text{ m})} = 3.05 \frac{m}{s} \approx 3.0 \frac{m}{s} \]

(b) (6 points) If the spring gun has spring constant \( k = 60 \text{ N/m} \), how far, \( d \), was the spring originally compressed?

\[ \begin{aligned} \text{at} \quad x = 0, \quad v_t = 0, \quad \frac{k}{2} d^2 = \frac{m}{2} v_i^2 \\ \text{W = \Delta K \quad where} \quad W = W_s = -\frac{k}{2} (x_f^2 - x_i^2) = \frac{k}{2} d^2, \quad \Delta K = K_f - K_i = \frac{m}{2} v_f^2 \end{aligned} \]

\[ d = v_i \sqrt{\frac{m}{k}} = (3.05\frac{m}{s}) \sqrt{\frac{0.2 \text{ kg}}{60 \frac{N}{m}}} = 0.176 \text{ m} \approx 0.18 \text{ m} \]

(c) (6 points) What is the speed \( v \) of the ball when it has fallen by \( H/2 \)?

\[ W_g = \frac{mgH}{2}, \quad \Delta K = K_{v_a} - K_i = \frac{m}{2} (v_a^2 - v_i^2) \]

\[ W = \Delta K \]

\[ mg \frac{H}{2} = \frac{m}{2} (v_a^2 - v_i^2) \]

\[ v_c = \sqrt{v_i^2 + gH} = \sqrt{(3.05\frac{m}{s})^2 + (9.8\frac{m}{s^2})(0.8 \text{ m})} = 4.14 \frac{m}{s} \]

\[ v_c \approx 4.1 \frac{m}{s} \]

(could use point C and final point, too) \[ v_c = \sqrt{v_i^2 + gH} = \sqrt{(5\frac{m}{s})^2 - (9.8)(0.8) - 4.1} \]
**Question #1 (16 points):**

A block of mass $M$ is attached to a spring (spring constant $k$) via a massless rope over a massless and frictionless pulley as shown in the figure. This block is held stationary at the position where the spring is uncompressed and is then released to slide down a frictionless inclined plane.

(i) (6 points) When the block is released it starts to move down the incline, momentarily stopping after moving a distance $d$. At some position, between 0 and $d$, the block reaches a maximum velocity. Mark each statement below that describes the condition where the velocity is a maximum.

(a) The gravitational potential energy is a maximum.
(b) The spring potential energy is a minimum.
(c) The kinetic energy is a maximum.
(d) The total potential energy is a minimum.
(e) None of the above describes the condition for maximum velocity.

(ii) (5 point) In this problem there is work done by the gravitational force on the block and by the tension in the rope, which is related to the extension of the spring. If the coordinate system is set up so that $+x$ is down the plane and $x=0$ is position of the block when the spring is unstretched, mark each statement below which is correct.

(a) When the velocity is a maximum (on the way down) the magnitude of the work done by gravity exceeds the magnitude of the work done by tension.
(b) When the velocity is a maximum the magnitude of the work done by tension exceeds the magnitude of the work done by gravity.
(c) When the velocity is a maximum the acceleration is zero. Because $F_{net} = 0$.
(d) When the block stops at $x=d$, the magnitude of the work done by gravity is equal to the magnitude of the work done by tension (spring).
(e) When it is moving back up the incline from $x=d$ towards $x=0$ the position where the speed is a maximum again is not the same as it was on the way down.

(iii) (5 point) The maximum magnitude of the tension of the rope is

(a) when $x=0$
(b) when $x=-d$
(c) when $x=d$.
(d) independent on $x$.
(e) None of the above is true.

\[ |T| = |F_s| \]

*the cord is stretched on the way down the incline

(if we consider motion up the incline, too

the tension has maximum magnitude at $x=-d$, too)
Problem #2 (17 points): The figure gives the acceleration of a 2.0 kg particle as an applied force \( F_a \) moves from rest along an \( x \) axis from \( x = 0 \) to \( x = 9.0 \) m, which takes in total 35 seconds. The scale of the figure’s vertical axis is set by \( a_s = 3.0 \) m/s\(^2\).

\( m = 2 \) kg,

(a) (6 points) How much work has the applied force done on the particle when the particle reaches \( x = 4.0 \) m?

\[
W = m \left( \text{area} \left[ 0 \to 4 \right] \right) = (2 \text{ kg}) \left( \frac{3(1)}{2} + 3(3) \right)
\]

\[
W = 21.0 \text{ J}
\]

(b) (6 points) How much work has the applied force done on the particle when the particle reaches \( x = 9.0 \) m?

\[
W = m \left( \text{area} \left[ 0 \to 9 \right] \right) = (2 \text{ kg}) \left( 3(4) - 3(3) \right) = 6.0 \text{ J}
\]

\[
W_{09} = 6.0 \text{ J}
\]

(c) (5 points) How much is the average power of the applied force on the particle?

\[
P_{\text{avg}} = \frac{W}{\Delta t} = \frac{6.0 \text{ J}}{35 \text{ s}} = 0.171 \text{ W}
\]

\[
P_{\text{avg}} \approx 0.17 \text{ W}
\]
**Question #2 (15 points):** A loaded penguin sled weighing 85.0 N rests on a plane inclined at angle $\theta = 30.0^\circ$ to the horizontal and is acted on, as shown, by an external force of magnitude $F=120$ N. Between the sled and the plane, the coefficient of kinetic friction is 0.150. The sled moves up the plane starting from rest. At the moment the sled has moved a distance $x=2.50$ m, as measured along the plane, find:

$$m g = 85 \text{N} \quad \mu = 0.15 \quad F = 120 \text{N}$$

(i) (5 points) How much work was done by gravity on sled?

(a) 78 J  
(b) -106 J  
(c) -127 J  
(d) -84 J  
(e) 89 J

$$W_g = -m g x \sin \theta = -\frac{(85)(2.5)}{85} \sin 30^\circ = -106.2 \text{ J}$$

(ii) (5 points) How much work was done by the frictional force?

(a) -17.8 J  
(b) -34.2 J  
(c) 11.5 J  
(d) -27.6 J  
(e) 43.1 J

$$W_f = -F_x x = -\mu (m g \cos \theta) x = -0.15 \cdot 85 \cdot 30^\circ \cos 30^\circ \cdot 2.5 \text{ m} = -27.6 \text{ J}$$

(iii) (5 points) What is the speed $v$ of the sled when it reaches 2.5 m?

(a) 6.19 m/s  
(b) 11.8 m/s  
(c) 4.50 m/s  
(d) 5.80 m/s  
(e) 3.70 m/s

$$W = \Delta K$$

$$W_F + W_g + W_f + W_{\text{fr}} = \Delta K = K_f - K_i = \frac{1}{2} m v^2$$

$$W_F = F x$$

$$v = \sqrt{\frac{2}{m} (F x + W_g + W_{\text{fr}})} = \sqrt{\frac{2(9.8 \frac{m}{s^2})(120 \text{N})(2.5 \text{m}) - 106.2 - 27.6}{85 \text{N}}}$$

$$v = 6.19 \text{ m/s}$$
Problem #3 (22 points): Show your work

A small block of mass \( m = 0.050 \text{ kg} \) can slide along the frictionless loop-the-loop, with loop radius \( R = 15 \text{ cm} \). The block is released from rest at point \( P \), at the height \( h \) above the bottom of the loop.

(a) (10 points) What is the minimum height \( h \) so that the block makes it around the loop?

- Minimum height \( \Rightarrow \) minimum speed at the top \( \Rightarrow \) normal force is zero: \( F_N = 0 \)

\[
mg + F_N = \frac{mv^2}{R}
\]

\[
v = \sqrt{\frac{gR}{2}} \quad \text{on the top of the loop the loop}
\]

\[
h_{\text{min}} = \frac{5}{2} R \quad \Rightarrow h = 2.5R = 2.5(0.15 \text{m}) = 0.375 \text{m} \quad \text{v is minimum when } F_N = 0
\]

(b) (6 points) If the block starts at the minimum height obtained from (a), what is the kinetic energy at the point \( Q \)?

\[
(K + U)_P = (K + U)_Q
\]

\[
mg(h - R) = Q \quad + 0
\]

\[
Q = mg(h - R) = (0.05 \text{ kg})(0.375 \text{ m} - 0.15 \text{ m})(9.8 \text{ m/s}^2)
\]

\[
Q = 0.11 \text{ J}
\]

(c) (6 points) How much work does the gravitational force do on the block as the block travels from point \( P \) to point \( Q \)?

\[
W_{\text{PQ}} = mgh_{\text{PQ}} = mg(h - R) = 1.5mgR = (1.5)(0.05 \text{ kg})(9.8 \text{ m/s}^2)(0.15 \text{ m})
\]

\[
h - R = 1.5R
\]

\[
W_{\text{PQ}} = 0.11 \text{ J}
\]

One could also use \( W = \Delta K \) where \( \Delta K = K - K_P = Q \) and \( W = W_g \) \( \Rightarrow \) therefore \( W_g = Q \), as is written above: \( W = 0.11 \text{ J} \)
Question #3 (12 points):

The figure at right shows a block of mass $m = 0.50$ kg which is attached to a spring with $k = 30$ N/m. The block is released from rest from the position $y=0$ when the spring is uncompressed. Assume positive $y$ is upwards.

(i) (4 points) What is the block's position, $y$, when it comes to rest at its minimum height?

(a) -0.25 m  
(b) -0.33 m  
(c) -0.09 m  
(d) -0.12 m  
(e) -0.17 m

\[ y = -0.3274 \leq |y| = \frac{2mg - (2)(0.5)(9.8)(0.163)}{30} \text{ downward} \]

(ii) (4 points) At what position $y$ is the net force on the block zero?

(a) -0.12 m  
(b) -0.06 m  
(c) -0.22 m  
(d) -0.16 m  
(e) -0.19 m

\[ F_{\text{net}} = mg - k|y| = 0 \Rightarrow |y| = \frac{mg}{k} = \frac{1}{2} \text{ of the previous value} \]

\[ |y| = 0.163 \text{ m downward} \]

(iii) (4 points) What is the maximum speed of the block?

(a) 1.27 m/s  
(b) 2.38 m/s  
(c) 0.63 m/s  
(d) 1.85 m/s  
(e) 3.15 m/s

\[ \frac{1}{2} v_f^2 = mg|y_m| - \frac{k}{2}|y_m|^2 \]

\[ v_f = \sqrt{\frac{2}{m}(mg|y_m| - \frac{k}{2}|y_m|^2)} \]

\[ = \sqrt{\frac{2}{0.5}(0.5)(9.8)(0.163) - \frac{30}{2}(0.163)^2} \]

\[ = 1.265 \text{ m/s} \approx 1.27 \text{ m/s} \]