PHYSICS-2101 Spring Semester 2013
Examination 1
Feb. 5, 2012

Instructor and section (circle yours)
McElgin (1) McElgin (2) McElgin (3)
Rupnik (4) Rupnik (5) Zhang (7)
Beaird (8) Jin (9) Beaird (10)

Name (print) KEY - LBP LSU ID _______________________

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 2 questions, totaling 100 points. Examine your formula sheet as well.

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 (20 points): Show your work.

In the figure, a 5.0 kg block is sent sliding up a plane inclined at $\theta = 37^\circ$ while a horizontal force $F$ of magnitude 50 N acts on it. The coefficient of kinetic friction between block and plane is 0.30.

(a) (5 points) Draw a free-body diagram for the forces acting on the block, carefully labeling each of the forces.

(b) (3 points) Find the normal force acting on the block.

$$ F_{\text{net},y} = 0 \quad \Rightarrow \quad F_N = F \sin \theta - mg \cos \theta = 0 $$

$$ F_N = mg \cos \theta $$

$$ F_N = (5.0 \text{ kg})(9.8 \text{ m/s}^2) \cos (37^\circ) $$

$$ F_N = 69.2 \text{ N} $$

(c) (6 points) Find the magnitude and direction (up or down the plane) of the block’s acceleration.

$$ F_{\text{net},x} = ma_x \quad \Rightarrow \quad ma_x = F \cos \theta - mg \sin \theta - F_k $$

$$ m = F \cos \theta - mg \sin \theta - F_k $$

$$ a_x = \frac{F \cos \theta - mg \sin \theta - F_k}{m} $$

$$ a_x = \frac{(50 \text{ N}) \cos 37^\circ - (5.0 \text{ kg})(9.8 \text{ m/s}^2) \sin (37^\circ) - 0.30 (69.2 \text{ N})}{5 \text{ kg}} $$

$$ a_x = -2.06 \text{ m/s}^2 $$

(d) (6 points) The block’s initial speed is 4.0 m/s, how far up the plane does the block go?

1. Acceleration is constant.
2. $+x$ is "up ramp."

$$ x_f - x_i = v_{ox}t + \frac{1}{2}a_x t^2 $$

$$ \Delta x(t) = v_{ox}t + \frac{1}{2}a_x t^2 $$

$$ \Delta x(t) = (4.0 \text{ m/s})t - \frac{1}{2}(2.06 \text{ m/s}^2)t^2 $$
**Question #1 (20 points):**

The figure shows a plot of potential energy $U$ versus position $x$ for a particle that can travel only along the $x$ axis. (Nonconservative forces are not involved.)

The particle is initially at $x = 3.0 \text{ m}$ moving rightward with the mechanical energy $E_{\text{mech}} = 9.0 \text{ J}$.

(Clearly circle your answers to each part below.)

(a) (4 points) During its motion, the particle will encounter ____________.

- (i) one turning point  
- (ii) two turning points  
- (iii) no turning points

(b) (6 points) If the particle is headed to the left, what is its kinetic energy at $x = 4.0 \text{ m}$?

- (i) 1.0 J  
- (ii) 5.0 J  
- (iii) 8.0 J  
- (iv) 9.0 J  
- (v) 0.0 J

$$E_{\text{mech}} = K + U$$
$$K = E_{\text{mech}} - U = 9 \text{ J} - 4 \text{ J} = 5 \text{ J}$$

(c) (4 points) If the particle is headed to the right, what is the best approximate value of the $x$ coordinate of its turning point?

- (i) 5.0m  
- (ii) 5.75m  
- (iii) 6.0 m  
- (iv) 7.0 m  
- (v) This cannot be determined.  
- (vi) There is no turning point.

(d) (6 points) What is the force acting on the particle at $x = 3.0 \text{ m}$?

- (i) $+2.0 \text{ N } \hat{i}$  
- (ii) $-2.0 \text{ N } \hat{i}$  
- (iii) $+4.0 \text{ N } \hat{i}$  
- (iv) $-4.0 \text{ N } \hat{i}$  
- (v) $+5.0 \text{ N } \hat{i}$  
- (vi) $-5.0 \text{ N } \hat{i}$  
- (vii) 0.0 N (i.e., no force at $x = 3.0 \text{ m}$)

$$F_x = \frac{-\Delta U}{\Delta x} = -\frac{(-4 \text{ J})}{2 \text{ m}}$$

$$F_x = +2 \text{ N}$$
Problem #2 (20 points): Show your work

A stone is projected at a cliff of height \( h \) with an initial speed of 42.0 m/s directed at an angle \( \theta_0 = 60^\circ \). The stone strikes at point A, 5.50 s after launching. Find:

(a) (7 points) the height \( h \) of the cliff;

\[
y_f = y_0 + v_{oy} t - \frac{1}{2} gt^2 \\
y_f = (v_0 \sin \theta_0) t - \frac{1}{2} gt^2 \\
\Rightarrow (42.0 \text{ m/s}) \sin (60^\circ) (5.50) - \frac{1}{2} (9.8 \text{ m/s}^2)(5.50)^2 = 51.83 \text{ m}
\]

(b) (7 points) the speed of the stone just before impact at point A;

\[
v_{ox} = v_{fx} \quad \text{but} \quad ax = 0 \\
v_{fx} = v_0 \cos \theta_0 = (42.0 \text{ m/s}) \cos (60^\circ) \\
v_{fx} = 21.0 \text{ m/s}
\]

\[
v_{fy} = v_{oy} - gt \\
v_{fy} = v_0 \sin \theta_0 - gt = (42.0 \text{ m/s} \sin (60^\circ)) - (9.8 \text{ m/s}^2)(5.50) \\
v_{fy} = -17.5 \text{ m/s}
\]

\[
\text{Speed} \quad |v_f| = \sqrt{v_{fy}^2 + v_{fx}^2} = \sqrt{(-17.5 \text{ m/s})^2 + (21.0 \text{ m/s})^2} = 27.3 \text{ m/s}
\]

(c) (6 points) the maximum height \( H \).

\[
v_{fy}^2 = v_{oy}^2 - 2g\Delta y \\
\Rightarrow 0 = v_0^2 \sin^2 \theta_0 - 2g(H + h) \\
\Rightarrow H = \frac{v_0^2 \sin^2 \theta_0}{2g} = \frac{(42 \text{ m/s})^2 \sin^2 (60^\circ)}{2(9.8 \text{ m/s}^2)}
\]

\[H = 67.5 \text{ m}\]
Problem #3 (20 points): Show your work

A skier is initially located on the top of a hemispherical ice mound of radius \( R \). He begins to slide down the ice, with a negligible initial speed (see the schematic figure). Approximate the ice as being frictionless.

(a) (8 points) Draw a free-body diagram for the forces acting on the skier and indicate which forces contribute to the centripetal force before the skier leaves the surface.

only \( F_n \) and \( mg \cos \alpha \) contribute to centripetal force.

(In fact \( F_c = mg \cos \alpha - F_n = ma_c \))

(b) (12 points) At what angle \( \alpha \) does the skier loss contact with the ice surface?

1. "Lose contact" \( \Rightarrow F_n = 0 \) \( \therefore F = mg \cos \alpha = ma_c \)

or \( g \cos \alpha = a_c = \frac{V^2}{R} \)

2. \( V^2 \) obtain through Emech conservation:

\( mgR + K_o = mg(R \cos \alpha) + K_f \)

or \( mg \cos \alpha \) \( = mgR \cos \alpha + \frac{1}{2} m V^2 \)

or \( 2gR = 2gR \cos \alpha + V^2 \)

\( 2gR = 2gR \cos \alpha + gR \cos \alpha \)

\( 2 = 2 \cos \alpha + \cos \alpha \)

or \( 2 = 3 \cos \alpha \)

\( \Rightarrow \alpha = \cos^{-1} \left( \frac{2}{3} \right) \)

\( \alpha = 48.2^\circ \)
Question #2 (20 points):
A block of mass $m = 0.5$ kg is dropped onto a spring at rest from a position above the spring. The block becomes attached to the spring and compresses it by distance $d = 0.2$ m before momentarily stopping. Assume that the spring constant $k = 98.0$ N/m and the air friction as well as the mass of the spring is negligible.

(a) (6 points) Is the mechanical energy conserved during whole motion (from the top position all the way to the lowest position)?

1. No  
2. Yes  
3. It cannot be determined  
4. Only the gravitational potential energy is conserved

\[ W_{\text{cons}} = 0 \quad \text{so} \quad \Delta E_{\text{mech}} = 0. \]

(a) (6 points) Which of the following statements is wrong?

1. The gravitational force is a conservative force.  
2. The restoring force from the spring is a conservative force.  
3. From the highest position to the lowest position, the net work done by all the forces acting on the block is zero.  
4. Only the elastic potential energy is conserved during the process.

\[ \text{Conservation law is for total mechanical energy.} \]
\[ \text{No such law for just potential energy.} \]

(b) (8 points) The initial height $h$ (above the top of the relaxed spring) is

1. Unable to be calculated from the given quantities  
2. 0.2 m  
3. 0.4 m  
4. 0.6 m

\[ \Delta K = K_f - K_0 = 0. \quad \Rightarrow \quad W_{\text{tot}} = 0 \]

\[ W_{\text{tot}} = W_g + W_s \]

\[ \Rightarrow \quad 0 = mg(h+d) - \frac{1}{2} kd^2 \]

\[ \Rightarrow \quad 0 = h + d - \frac{kd^2}{2mg} \]

\[ \Rightarrow \quad h = \frac{kd^2}{2mg} - d = \frac{(980)(0.2)^2}{2(0.5)(9.8)} = 0.2m \]

\[ h = 0.4m - 0.2m = 0.2m, \]
Problem #2 (20 points): Show your work

You throw a ball toward a wall at a speed of 25.0 m/s and at an angle of $\theta_0 = 40^\circ$. The wall is a distance $d = 22.0$ m from the release point of the ball.

(a) (7 points) How far above the release point does the ball hit the wall?

\[ d = V_{ox} \cdot t \quad \Rightarrow \quad t = \frac{d}{V_{ox}} = \frac{d}{V_0 \cos \theta_0} \]
\[ y_f = 0 + V_{oy}t - \frac{1}{2}gt^2 \]
\[ = (V_0 \sin \theta_0) \left( \frac{d}{V_0 \cos \theta_0} \right) - \frac{9.8 \cdot d^2}{2V_0^2 \cos^2 \theta_0} \]
\[ y_f = d - \frac{9.8 \cdot 22^2}{2 \cdot 25^2 \cos^2 40^\circ} = 22.0 m - \frac{(9.8 m/s^2)(22.0 m)^2}{2(25 m/s)^2(\cos 40^\circ)^2} \]
\[ y_f = 15.5 m \]

(b) (7 points) What are the horizontal and vertical components of the its velocity as it hits the wall?

\[ V_{fx} = V_{ox} + a_{xt} = V_0 \cos \theta_0 = 25.0 m/s \cos 40^\circ = 19.15 m/s \]
\[ V_{fy} = V_{oy} - g \cdot t = V_0 \sin \theta_0 - \frac{9.8 \cdot d}{V_0 \cos \theta_0} \]
\[ = (25 m/s) \sin 40^\circ - \frac{(9.8 m/s^2)(22.0 m)}{(25 m/s) \cos 40^\circ} = 4.81 m/s \]
\[ \boxed{V_{fx} = 19.2 m/s} \quad \boxed{V_{fy} = 4.81 m/s} \]

(c) (6 points) When it hits, has it passed the highest point on its trajectory?

\[ t_f = \frac{d}{V_0 \cos \theta_0} = \frac{22 m}{(25 m/s) \cos 40^\circ} = 1.1487 s = t_f \]

\[ t_{peak} : \quad V_{fy} = 0 = V_{oy} - g \cdot t_{peak} \]
\[ t_{peak} = \frac{V_{oy}}{g} = \frac{V_0 \sin \theta_0}{g} = \frac{(5 m/s) \sin 40^\circ}{9.8 m/s^2} \]
\[ t_{peak} = 1.640 s \]

\[ \text{It has NOT passed peak in trajectory.} \]

\[ \text{b/c } t_f < t_{peak} \]
Problem #3 (20 points): Show your work

A block with mass \( m = 3.0 \text{ kg} \) is placed against a spring on a frictionless incline with angle \( \theta = 30^\circ \). (The block is not attached to the spring.) The spring, with spring constant \( k = 20 \text{ N/cm} \), is compressed a distance \( d = 20 \text{ cm} \) and then released.

(a) (5 points) How much total work is done on the block as it travels from its release point to its highest point? Justify your answer without referring to particular forces

\[
\begin{align*}
\text{Begins at rest & ends at rest,} \\
\Delta K &= K_f - K_i = 0 \\
\text{So} \\
W_{\text{tot}} &= \Delta K = 0 \\
\text{Note: No reference to forces!}
\end{align*}
\]

(b) (5 points) What is the elastic potential energy of the compressed spring before the block is released?

\[
U_{s,0} = \frac{1}{2} kd^2 = \frac{1}{2} \left(2000 \frac{\text{N}}{\text{m}}\right)(0.2 \text{ m})^2 = 40 \text{ J}
\]

\[U_{s,0} = 40 \text{ J}\]

(c) (5 points) What is the change in the gravitational potential energy of the block–Earth system as the block moves from the release point to its highest point on the incline?

\[
W_{\text{cons.}} = 0 \quad \text{so} \quad E_i = E_f
\]

\[
\begin{align*}
&\Delta U_g = U_{i,g} - U_{f,g} \\
&\quad = U_{s,0} + U_{g,0} - U_{s,0} - U_{g,0} \\
&\quad = 
\end{align*}
\]

\[
\Delta U_g = 40 \text{ J}
\]

(d) (5 points) How far along the incline is the highest point from the release point?

\[
L = h \sin \theta \quad \text{and} \quad \Delta U_g = mgh \quad \Rightarrow \quad h = \frac{\Delta U_g}{mg}
\]

\[
L = \frac{40 \text{ J}}{(3 \text{ kg})(9.8 \text{ m/s}^2)} \sin(30^\circ) = 1.02 \text{ m}
\]

\[L = 1.02 \text{ m}\]