Indiana University
PHYSICS P221, Fall 2007
Practice Exam 2

*_Do not turn the page until instructed to begin._*

*Instructions:*  
- Write your name and seat number on the front of the blue books.  
- Write all your work including answers in the blue exam books provided. Don’t forget your name! You may keep the exam.  
- For multiple choice problems only the answer will be graded and no partial credit given.  
- For long-answer problems, show your work, as credit will not be given for an answer only. Also, partial credit may be given.  
- Don’t forget units and answer with vector (not just a magnitude) when problem requires. Use correct number of significant figures.  
- This is a closed-book examination. You may not refer to lecture notes, textbooks, or any other course materials.  
- A list of (possibly) useful formulas is attached to this end of this exam.  
- You may use a calculator, but solely for the purpose of arithmetic computation.  
- There are 7 problems on this exam, 4 multiple choice, and 3 long-answer (with multiple parts). Point values are indicated with each problem.

*Good Luck!*_
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Multiple Choice Problems:

1) (5 pts) When I stretch a certain spring by 1 m from its resting length it stores a certain amount of potential energy. When I stretch it an additional 1 m, it now has

A. One quarter the potential energy  
B. One half the potential energy  
C. The same potential energy  
D. Twice the potential energy  
E. Four times the potential energy

2) (5 pts) A spring (shown in figure) hangs at rest (1). You attach the mass to the spring, hold it for a moment and let go (2). A while later, the mass is momentarily at rest at a lower position (3). Comparing the situation in (2), to that in (3),

A. Gravity has done positive work and the spring negative work on the mass.  
B. Gravity has done positive work and the spring positive work on the mass.  
C. Gravity has done negative work and the spring negative work on the mass.  
D. Gravity has done negative work and the spring positive work on the mass.
3 (5 pts) Consider the two ramps shown. If the ramps have kinetic friction (the same value for both ramps), which one requires less work for you to push a block from rest at the bottom to rest at the top?

A. Left
B. Right
C. Same
D. Need more information to determine.

4 (5 pts) As a particle moves along the $x$ axis it is acted upon by a conservative force. The potential energy is shown below as a function of the coordinate $x$ of the particle. Rank the labeled regions according to the magnitude of the force, least to greatest.

A. AB, BC, CD
B. AB, CD, BC
C. BC, CD, AB
D. BC, AB, CD
E. CD, BC, AB
Long Answer Problems:

5) (24pts) A 150 kg crate, starting from rest, slides 2.5 m down a ramp (measured along the ramp) inclined at 30° w.r.t. horizontal. The coefficient of kinetic friction between the crate and the ramp is 0.20. Be careful to indicate the correct sign in your answers to (a) and (b) below.

a) (8 pts) What is the work done by the frictional force on the crate?

b) (8 pts) What is the work done by the gravitational force on the crate?

c) (8 pts) What is the speed of the crate at the bottom of the ramp?

6) (16pts) Three masses are connected using massless, rigid rods such that the rods meet at right angles and each mass is 3 meters from the origin as shown in the figure. The balls have equal masses, $m_1 = m_2 = m_3 = 2 \text{ kg}$.

![Diagram of three masses connected by rods](image.png)

a) (8 pts) Calculate the position vector $\vec{r}_{COM}$ of the center of mass of this object.

b) (8 pts) If a force $\vec{F} = (6 \text{ N})\hat{j}$ is applied to $m_1$, what is the displacement vector of the center of mass from its original position after $t = 2 \text{ s}$?
7) (32pts) The figure shows a ball with a mass, \( m = 1.5 \text{ kg} \) on the end of a massless string. The ball swings down and collides \textit{elastically} with a stationary block of mass, \( M = 2.5 \text{ kg} \), at the bottom of its swing. The ball starts at rest a height, \( h = 0.50 \text{ m} \), above the block. Neglect friction and air resistance when answering the questions below.

a) (8 pts) What is the speed of the ball just before the collision?

b) (8 pts) What is the speed of the block just after the collision?

c) (8 pts) After the collision does the ball continue forward or rebound backward?

d) (8 pts) What is the maximum height that the ball reaches after the collision?
P221 Fall 2007 Formula Sheet

Miscellaneous
Quadratic Formula:
\[ ax^2 + bx + c = 0; \]
\[ x = \frac{1}{2a} \left(-b \pm \sqrt{b^2 - 4ac}\right) \]

Motion in 1 dimension
Displacement: \[ \Delta x = x_2 - x_1 \]
Average Velocity: \[ v_{ave} = \frac{\Delta x}{\Delta t} \]
Average Speed: \[ s_{ave} = \frac{\text{total distance}}{\Delta t} \]
Instantaneous Velocity: \[ v = \frac{dx}{dt} \]
Average Acceleration: \[ a_{ave} = \frac{\Delta v}{\Delta t} \]
Instantaneous Acceleration: \[ a = \frac{dv}{dt} = \frac{d^2x}{dt^2} \]
Constant Acceleration:
\[ v = v_0 + at \]
\[ x - x_0 = v_0 t + \frac{1}{2}at^2 \]
\[ v^2 = v_0^2 + 2a(x - x_0) \]
\[ x - x_0 = \left(\frac{v_0 + v}{2}\right)t \]
\[ x - x_0 = vt - \frac{1}{2}at^2 \]
Free-fall acceleration: \[ g = 9.8 \text{ m/s}^2 \]

Vectors
Components of a vector:
\[ a_x = a \cos \theta \quad \text{and} \quad a_y = a \sin \theta \]
\[ a = \sqrt{a_x^2 + a_y^2} \quad \text{and} \quad \tan \theta = \frac{a_y}{a_x} \]

Unit-Vector Notation: \[ \vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k} \]
Scalar Product:
\[ \vec{a} \cdot \vec{b} = ab \cos \theta = a_x b_x + a_y b_y + a_z b_z \]
Vector Product:
\[ |\vec{a} \times \vec{b}| = ab \sin \phi \]
\[ \vec{a} \times \vec{b} = \]
\[ (a_y b_z - a_z b_y) \hat{i} + (a_z b_x - a_x b_z) \hat{j} + (a_x b_y - a_y b_x) \hat{k} \]

Motion in 2,3 Dimensions
Position Vector: \[ \vec{r} = xi + yj + zk \]
Displacement: \[ \Delta \vec{r} = \vec{r}_2 - \vec{r}_1 = \Delta x \hat{i} + \Delta y \hat{j} + \Delta z \hat{k} \]
Average and Instantaneous Velocity:
\[ \vec{v}_{ave} = \frac{\Delta \vec{r}}{\Delta t} \]
\[ \vec{v} = \frac{d\vec{r}}{dt} \]
\[ \vec{v} = v_x \hat{i} + v_y \hat{j} + v_z \hat{k} \]
Average and Instantaneous Acceleration:
\[ \vec{a}_{ave} = \frac{\Delta \vec{v}}{\Delta t} \]
\[ \vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2} \]
\[ \vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k} \]
Projectile Motion:
\[ x - x_0 = (v_0 \cos \theta_0) t \]
\[ y - y_0 = (v_0 \sin \theta_0) t - \frac{1}{2}gt^2 \]
\[ v_y = v_0 \sin \theta_0 - gt \]
\[ v_y^2 = (v_0 \sin \theta_0)^2 - 2g(y - y_0) \]
\[ R = \frac{v_0^2}{g} \sin 2\theta_0 \]
Uniform Circular Motion:
\[ a = \frac{v^2}{R}; T = \frac{2\pi r}{v} \]

Force and Motion
Newton’s Second Law: \[ \vec{F}_{net} = m\vec{a} \]
Gravitational Force: \[ F_g = mg \]
Weight: \[ W = mg \]
Static Friction: \[ f_{s,max} = \mu_s F_N \]
Kinetic Friction: \[ f_k = \mu_k F_N \]
Drag Force: \[ D = \frac{1}{2}Cho A v^2 \]
Terminal Speed: \[ v_t = \sqrt{\frac{2F_g}{C\rho A}} \]
Kinetic Energy and Work

Kinetic Energy: \( K = \frac{1}{2}mv^2 \)

Work Done by Constant Force: \( \mathbf{F} \cdot \mathbf{d} = Fd \cos \phi \)

Work and Kinetic Energy: \( \Delta K = K_f - K_i = W \)

Work Done by Gravity: \( W_g = mgd \cos \phi \)

Spring Force: \( \mathbf{F} = -k \mathbf{d} \)

Work Done by Spring Force: \( W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2 \)

Work Done by Variable Force: \( W = \int_{x_i}^{x_f} F(x) \, dx \)

Power: \( P_{\text{avg}} = \frac{W}{\Delta t}, P = \frac{dW}{dt}, P = Fv \cos \phi = \mathbf{F} \cdot \mathbf{v} \)

P.E. and Conservation of Energy

Potential Energy: \( \Delta U = -W = -\int_{x_i}^{x_f} F(x) \, dx \)

Gravitational Potential Energy: \( \Delta U = mgd; U(y) = mgy \)

Elastic Potential Energy: \( U(x) = \frac{1}{2}kx^2 \)

Mechanical Energy: \( E_{\text{mec}} = K + U \)

Cons. of Mech. Energy: \( \Delta E_{\text{mec}} = 0 \)

Potential Energy Curves: \( F(x) = -\frac{dU}{dx} \)

Work Done on System by an Ext. Force:

... no friction: \( W = \Delta E_{\text{mec}} \)

... with friction: \( W = \Delta E_{\text{mec}} + \Delta E_{\text{th}}; \)

\( \Delta E_{\text{th}} = fkd \)

Conservation of Energy:

\( \Delta E_{\text{mec}} + \Delta E_{\text{th}} + \Delta E_{\text{int}} = 0 \)

COM and Linear Momentum

Center of Mass: \( \mathbf{r}_{\text{com}} = \frac{1}{M} \sum_{i=1}^{n} m_i \mathbf{r}_i \)

Linear Momentum of Particle: \( \mathbf{p} = m \mathbf{v} \)

Linear Momentum of System: \( \mathbf{P} = M \mathbf{v}_{\text{com}} \)

Newton’s 2nd law for System:

\( \mathbf{F}_{\text{net}} = M \mathbf{a}_{\text{com}}; \mathbf{F}_{\text{net}} = \frac{d\mathbf{P}}{dt} \)

Cons. of Linear Momentum: \( \Delta \mathbf{P} = 0 \)

Impulse: \( \mathbf{J} = \int_{t_i}^{t_f} \mathbf{F}(t) \, dt = \Delta \mathbf{p} \)

Inelastic Collision: \( \Delta \mathbf{P} = 0 \)

Elastic Collision: \( \Delta \mathbf{P} = 0; \Delta K = 0 \)