Instructions:

1. Write your name and discussion section time in the allotted spaces at the top of each sheet on the exam.
2. The exam is worth a total of 60 points. The points allocated to each part of each problem are indicated in parentheses before the problem statement.
3. Answer all of the questions. You must show all of your work on the attached sheets in order to receive full credit for correct answers or partial credit for incorrect answers.
4. Confine all of your work for a given problem to the sheet for that problem, using the back of the page if you need any additional space. This is important, because the sheets will be separated for grading.
5. State clearly any sign conventions you choose to use. Also indicate clearly what system you are analyzing in Newton's Laws applications.
6. You are not permitted to consult any notes or books during the exam. Calculators are allowed.
7. Ask the exam proctor if you have any questions regarding the wording of any problem.
8. Exam papers will be collected by 2:20 p.m. Good Luck!

Equations and constants you may find useful:

Constant $a_y \rightarrow v_y = v_{0y} + a_y t$; $y = y_0 + v_{oy} t + \frac{1}{2} a_y t^2$; $v_y^2 - v_{oy}^2 = 2a_y (y - y_0)$;

$y = y_0 + \frac{1}{2} (v_{oy} + v_y) t$;

$a_{centripetal} = v^2 / r$; $\vec{F}_{net} = m \vec{a}$; weight $= mg$; $f_{kinetic} = \mu_k N$; $f_{x, max} = \mu_s N$;

$F_{spring} = -kx$;

Work $= \int \vec{F} \cdot d\vec{s}$; Work done by conservative force $= U_i - U_f$;

SEE BACK OF PAGE FOR MORE EQUATIONS
\[ U_{\text{gravity near earth's surface}} = mgy; \quad U_{\text{spring}} = \frac{1}{2}kx^2 \]

\[ \Delta K + \Delta U = \text{Work done by other forces;} \]
only conservative force acting \( \Rightarrow K_i + U_i = K_f + U_f; \)

\[ \ddot{p} = m\ddot{v}; \quad \ddot{F}_{\text{net}} = d\ddot{p} / dt; \]

System of Particles:

\[ \ddot{F}_{\text{net}}^{\text{external}} = M_{\text{tot}} \ddot{a}_{\text{c.m.}} = \frac{d}{dt} \Sigma \ddot{p}_i; \quad \ddot{r}_{\text{c.m.}} = \frac{\Sigma m_i \ddot{r}_i}{\Sigma m_i}; \quad \ddot{v}_{\text{c.m.}} = \frac{\Sigma m_i \ddot{v}_i}{\Sigma m_i}; \]

\[ F_{\text{net}}^{\text{external}} = 0 \Rightarrow \Sigma \ddot{p}_i = \Sigma \ddot{p}_f; \]

Constants:

\[ g = 9.80 \text{ m/s}^2; \]

\[ \sin 30^\circ = \cos 60^\circ = 0.500; \quad \cos 30^\circ = \sin 60^\circ = 0.866; \quad \sin 45^\circ = \cos 45^\circ = 0.707; \]

roots of quadratic equation \( az^2 + bz + c = 0 \) are \[ z = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]
1. A child of mass 30 kg accelerates to a horizontal speed of 4.0 m/s and leaps onto his toy scooter of mass 5.0 kg. The scooter is initially at rest. Neglect any friction between the scooter and the pavement.

(a) [8 points] What is the final speed of the child-scooter system?

(b) [6 points] What change, if any, occurs in the kinetic energy of this system from just before to just after the child mounts the scooter?

(c) [6 points] Suppose the child acquires his speed of 4.0 m/s by starting from rest and running 8.0 m at a constant acceleration. What is the horizontal acceleration of the center-of-mass of the child-scooter system during his acceleration phase? Circle one of the answers below.
   i.  
   ii. 9.8 m/s^2  
   iii. 1.0 m/s^2  
   iv. 0.86 m/s^2  
   v. 2.00 m/s^2
2. A small block of mass $m = 1.5 \text{ kg}$ is released from rest at the top inner surface of a frictionless hemispherical bowl of 30 cm radius. The block slides down toward the bottom of the bowl, and then up the other side.

(a) [10 points] What is the magnitude of the normal force exerted by the bowl on the block when the block reaches the bottom of the bowl?

(b) [5 points] What is the magnitude of the block's centripetal acceleration at the point where half of its initial gravitational potential energy has been converted to kinetic energy?

(c) [5 points] Circle the statement below that most accurately describes an aspect of the normal force $N$ in this problem.

i. $N$ is equal and opposite to the block's weight at all points along the block's path.

ii. The magnitude of $N$ is constant as the block slides down the bowl.

iii. $N$ does negative work on the block as it slides downward, but positive work as the block slides back up the other side.

iv. $N$ does zero work on the block throughout its motion.

v. The magnitude of $N$ is always $\geq mg$. 
3. A 5.0 kg block is launched along a rough horizontal floor with initial velocity \( v_0 \), toward a spring of spring constant \( k = 500 \text{ N/m} \). The surface between the block and the floor is characterized by a coefficient of kinetic friction \( \mu_k = 0.25 \). The block travels 45.1 cm before hitting the spring, and then an additional 4.90 cm in compressing the spring, before coming momentarily to rest.

(a) [5 points] How much work is done by the frictional force on the block from the start of its travel up to the point where the spring is maximally compressed? Specify both the magnitude and the sign.

(b) [5 points] What was the block's initial speed \( v_0 \)?

(c) [5 points] Circle the one of the following graphs that represents the best characterization of the block's acceleration, as a function of position, during its rightward motion? Take rightward as the positive \( x \) direction and \( x = 0 \) as the block's starting point.

(d) [5 points] What is the minimal value for the coefficient of static friction (\( \mu_s \)) between the block and the floor that will prevent the block from further motion after the 4.90 cm compression of the spring?