Answer all questions, beginning each new question in the space provided. Show all work. Show all formulas used for each problem prior to substitution of numbers. Label diagrams and include appropriate units for your answers. Write your name and section number at the top of each page in the space provided and write the name of your section instructor in the place provided in the cover sheet. You may use an alphanumeric calculator (one which exhibits physical formulas) during the exam as long as you do not program any formulas into memory. By using an alphanumeric calculator you agree to allow us to check its memory during the exam. Simple scientific calculators are always OK!

**A Formula Sheet Is Attached To The Back Of This Examination**

For your convenience you may carefully remove it from the Exam. Please take it with you at the end of the exam or throw it in a waste basket.

**Be Prepared to Show your Student ID Card**

Score on each problem:

1. (24) ____
2. (12) ____
3. (25) ____
4. (30) ____
5. (30) ____
6. (25) ____
7. (24) ____
8. (30) ____

Total Score (out of 200 pts) ____
1. (24 point) Put a circle around the letter that you think is the best answer.

1.1. (4 pts) If a particle undergoes SHM with amplitude 0.15 m, what is the total distance it travels in one period?

A) 0.15 m  
B) 0.30 m  
C) 0.45 m  
D) 0.60 m  
E) none of the above

1.2. (4 pts) The position of a mass that is oscillating on a spring is given by

\[ x(t) = (3.0 \text{ m}) \cos[(2.0 \text{ s}^{-1})t]. \]

Write a value for the amplitude of the particle’s velocity

A) 1.5 m/s  
B) 6.0 m/s  
C) 2/3 m/s  
D) 12.0 m/s  
E) none of the above

1.3. (4 pts) A mass \( M \) is attached to a spring with spring constant \( k \). When this system is set in motion with amplitude \( A \), it has a period \( T \). What is the period if the amplitude of the motion is increased to \( 2A \)?

A) \( 2T \)  
B) \( T/2 \)  
C) \( \sqrt{T} \)  
D) \( 4T \)  
E) \( T \)

1.4. (4 pts) Two children are riding on a merry-go-round. Child A is at a greater distance from the axis of rotation than child B. Which child has the larger angular speed

A) Child A  
B) Child B  
C) They have the same zero angular speed.  
D) They have the same non-zero angular speed  
E) There is not enough information given to answer the question.
1.5. (4 pts) When you ride a bicycle, in what direction is the angular velocity of the wheels?

A) to your left
B) to your right
C) forwards
D) backwards
E) up

1.6. (4 pts) A ball drops some distance and gains 30 J of kinetic energy. Do not ignore air resistance. How much gravitational potential energy did the ball lose?

A) more than 30 J
B) exactly 30 J
C) less than 30 J
D) Cannot be determined from the information given
2. (12 pts)
   a) (5 pts) What is the maximum speed at which a car can round a curve of 25 m radius on a level road if the coefficient of static friction between the tires and road is 0.80?

   b) (7 pts) Two objects are moving as shown in the figure. What is the absolute value of their total angular momentum about point O?
3. (25 pts) One 2.0-kg paint bucket is hanging by a massless cord from another 2.0-kg paint bucket, also hanging by a massless cord, as shown in the figure.
   a) (3 pts) Draw free-body diagrams for each bucket.
   b) (10 pts) If the buckets are at rest, what is the tension in each cord?
   c) (12 pts) If the two buckets are pulled upward with an acceleration of \(1 m/s^2\) by the upper cord, calculate the tension in each cord.
4. (30 pts) A block of slippery cheese slides on a horizontal table at 10 m/s. It then slides up the wedge rigidly attached to the table as shown in the figure. The height of the wedge is h=1.8 m.

If friction is negligible,

a) (10 pts) What will be the value of velocity at the top of the incline, point A.

b) (20 pts) How far from the right edge of the wedge will the block travel before hitting the table?
5. (30 pts) A 0.50-kg mass is attached to a spring of spring constant 20 N/m along a horizontal, frictionless surface. The object oscillates in simple harmonic motion and has a speed of 1.5 m/s at the equilibrium position

a) (7pts) What is the amplitude of oscillations?

b) (8pts) What is the total mechanical energy?

c) (15pts) At what location are the kinetic energy and the potential energy the same?
6. (25 pts) A 30-g bullet traveling horizontally at 300 m/s strikes a 1.0-kg block which is attached to a horizontal spring with a force constant of 2000 N/m and rests on a frictionless horizontal surface. The spring is on the far side of the block and aligned with the direction of travel of the bullet. The bullet becomes embedded in the block and, as a result of the impact, and the block slides against the spring.

a) (10 pts) Calculate the velocity of the bullet and block system immediately after the bullet is stopped in the block.

b) (15 pts) How far is the spring compressed before it reverses its direction of travel?
7. (24 pts) A skater is spinning at 1 rev/s with her arms outstretched so that her moment of inertia is 3 kg m\(^2\). She then pulls her arms to her sides, which reduces her moment of inertia to 1.5 kg m\(^2\).

a) (10 pts) What is her new angular velocity?

b) (7 pts) What are her initial and final kinetic energies?

c) (7 pts) How much work does she have to perform to pull her arms in?
8. (30 pts) A shop sign weighing $m=20$ kg is supported by a uniform 10-kg beam as shown in the figure. The beam is 2.0 m long. A wire is attached to the center of the beam.
   a) (5 pts) Draw a free-body diagram of the beam.

   b) (25 pts) Find the tension in the wire and the horizontal and vertical forces exerted by the hinge on the beam.
Trig:
\[
\sin \theta = \frac{a}{c} \\
\cos \theta = \frac{b}{c} \\
\tan \theta = \frac{a}{b} \\
c^2 = a^2 + b^2
\]

**Quadratic Formula:**
\[
Ax^2 + Bx + C = 0\text{ has solutions:} \\
x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}
\]

**Misc Formulas:**
- Circumference of a circle = \(2\pi R\)
- Area of a circle = \(\pi R^2\)
- Surface Area of a Sphere = \(4\pi R^2\)
- Volume of sphere = \((4/3)\pi R^3\)
- Volume of cylinder = \(\pi R^2L\)

**Differentiation:**
\[
dx^n/dx = nx^{n-1} \quad (n \neq 0) \\
d\cos(x)/dx = -\sin(x) \quad (x \text{ in radians}) \\
d\sin(x)/dx = \cos(x) \quad (x \text{ in radians}) \\
d(f(x) + g(x))/dx = df(x)/dx + dg(x)/dx
\]

**Integration:**
\[
\int x^n \, dx = \frac{x^{n+1}}{n+1} + C
\]

**1-D Motion:**
- displacement = \(\Delta x\)
- \(v_{\text{average}}\): \(\Delta x/\Delta t = (x_2 - x_1)/(t_2 - t_1)\)
- \(a_{\text{average}}\): \(\Delta v/\Delta t = (v_2 - v_1)/(t_2 - t_1)\)

Given \(x(t)\)
\[
\begin{align*}
v(t) &= dx/dt \quad \text{(instantaneous)} \\
a(t) &= dv/dt = d^2x/dr^2 \\
&\quad \text{(instantaneous)}
\end{align*}
\]

**1-D Motion with Const. Acc.:**
\[
x(t) = (1/2)\, at^2 + v_0t + x_0 \\
v(t) = at + v_0 \\
v^2 = v_0^2 + 2a(x-x_0)
\]

**Projectile Motion:**
\[
x(t) = v_0t + x_0
\]

**Formulae**
\[
v_x(t) = v_{0x} \\
a_x(t) = 0 \\
y(t) = (1/2)\, a_y t^2 + v_{0y} t + y_0 \\
v_y(t) = a_y t + v_{0y} \\
a_y(t) = a_y
\]

For motion over level ground
- Range = \(\left[v_0^2 \sin(2\theta_0)/g\right]\)

**Acceleration due to gravity:**
\(g = 9.8 \text{ m/s}^2\) downward

**Newton's Second Law:**
\[
\vec{F}_{\text{net}} = \sum \vec{F}_{\text{ext}} = ma
\]

**Circular Motion:**
- \(a_{\text{centripetal}} = v^2/R\)
- \(T = 1/f\quad v = 2\pi R/T\)

**Frictional Forces:**
- \(f_s \leq \mu_s F_N\)
- \(f_k = \mu_k F_N\)
- \(\mu_s > \mu_k\)

**Work and Kinetic Energy**
\[
W = F \Delta x \\
W = \int F \, d\vec{r} \\
K = (1/2)m v^2 \\
W_{\text{net}} = \Delta K \\
\Delta K = K_f - K_i
\]

**Potential Energy**
\[
\Delta U = U(x) - U_0(x_0) = -\int_{x_0}^x F \, dx \\
F(x) = -dU(x)/dx
\]

For gravity on earth's surface:
- \(F_g = mg\)
- \(U(y) = U_0 + mgy\)

For gravity in general:
- \(F_g = -GmMe/R^2\)
- \(U(r) = -GmMe/R\)
For springs:
\[ F = -kx \]
\[ U(x) = \frac{1}{2}kx^2 \]

With conservative forces only:
\[ E_{\text{tot}} = K + U \quad \text{(a constant)} \]
\[ \Delta E_{\text{tot}} = \Delta K + \Delta U = 0 \]

With non-conservative forces:
\[ \Delta E_{\text{tot}} = \Delta K + \Delta U = W_{\text{NC}} \]

Kepler's third law:
\[ T^2/R^3 = \frac{4\pi^2}{GM_{\text{sun}}} \]
\[ G = 6.67 \times 10^{-11} \text{N.m}^2/\text{kg}^2 \]

Power
\[ P_{\text{avg}} = W/t \]
\[ P = dW/dt \]
\[ P = \vec{F} \cdot \vec{v} \]

**Momentum and Impulse**
\[ \dot{p} = mv \]
\[ \vec{F} = d\dot{p}/dt \]
\[ \vec{J} = \int \vec{F}dt = \vec{F}_v\Delta t \]
\[ \vec{J} = \Delta \dot{p} \]

For elastic collision:
\[ \dot{p}_A + \dot{p}_B = \dot{p}'_A + \dot{p}'_B \]
\[ \frac{1}{2}m_Av_A^2 + \frac{1}{2}m_Bv_B^2 = \frac{1}{2}m_Av'_A^2 + \frac{1}{2}m_Bv'_B^2 \]

For 1-D elastic head-on collisions:
\[ v_A - v_B = -(v'_A - v'_B) \]

**Center of Mass**
\[ r_{\text{cm}} = \Sigma m_i r_i / M \]
\[ \Sigma F_{\text{ext}} = Ma_{\text{cm}} \]

**Rotation**
\[ \omega = d\theta/dt \]
\[ \alpha = d\omega/dt \]

**For constant angular acceleration**
\[ \theta(t) = (1/2)\alpha t^2 + \omega_0 t + \theta_0 \]
\[ \omega(t) = \alpha t + \omega_0 \]
\[ \omega^2 = \omega_0^2 + 2\alpha (\theta - \theta_0) \]

\[ I = \Sigma m_i r_i^2 \]
\[ K_{\text{rot}} = \frac{1}{2}I\omega^2 \]
\[ K_{\text{tot}} = \frac{1}{2}I_{\text{CM}}\omega^2 + \frac{1}{2}Mv_{\text{CM}}^2 \]

**Στ = Iα**
\[ \vec{L} = \vec{r} \times \vec{p} \]
\[ \vec{L} = I\ddot{\omega} \]
\[ \ddot{r} = \vec{r} \times \vec{F} \]
\[ \tau = r F \sin \theta \]
\[ v_{\text{tangential}} = R\omega \]
\[ a_{\text{tangential}} = R\alpha \]
\[ a_R = \alpha^2 R \]

**Harmonic Motion**
\[ F = -kx \]
\[ U(x) = \frac{1}{2}kx^2 \]
\[ \omega = \sqrt{k/m} ; \quad T = 2\pi \sqrt{m/k} \]
\[ T = 2\pi/\omega ; \quad f = 1/T ; \quad \omega = 2\pi f \]

\[ x(t) = A\cos(\omega t + \phi) \]
\[ v(t) = -\omega A\sin(\omega t + \phi) \]
\[ a(t) = -\omega^2 A\cos(\omega t + \phi) \]

**Pendulums**
\[ T = 2\pi \sqrt{L/g} \]
\[ \omega = \sqrt{g/L} \]