Instructor: ______________________  Name: ______________________

Student Number: ______________________

# MEMORIAL UNIVERSITY OF NEWFOUNDLAND
## DEPARTMENT OF PHYSICS AND PHYSICAL OCEANOGRAPHY

**Physics 1050**

FINAL EXAMINATION April, 2007

INSTRUCTIONS:

1. THIS EXAMINATION PAPER CONSISTS OF 9 QUESTIONS ON 9 PAGES.
2. **DO 8 OUT OF 9 QUESTIONS**. ALL QUESTIONS CARRY EQUAL MARKS.
3. Write your name and student number on each page.
4. Feel free to remove the formula sheet.
5. You may use a calculator. All other aids are prohibited.
6. Use only the paper provided. No other books, notes or papers are permitted. The examination paper must not be taken from the room.
7. Write answers neatly in space provided. If necessary, continue onto the back of the page.
8. Do not erase or use "whiteout" to correct answers. Draw a line neatly through material to be replaced and continue with correction.
9. Don't panic. If something isn't clear, ASK!

For constant a:

$$x = x_0 + v_0 t + \tfrac{1}{2}at^2$$
$$v^2 = v_0^2 + 2a(x - x_0)$$
$$v = v_0 + at$$
$$x - x_0 = \tfrac{1}{2}(v + v_0)t$$

acceleration due to gravity: $g = 9.80 \text{ m/s}^s$

for uniform circular motion: $a_r = \dfrac{v^2}{r}$

$\sum \vec{F} = m\vec{a}$

$f_k = \mu_k n$

$f_s \le \mu_s n$

$\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$

$\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0$

$\hat{i}\times\hat{j} = \hat{k} \quad \hat{j}\times\hat{k} = \hat{i} \quad \hat{k}\times\hat{i} = \hat{j}$

$\hat{j}\times\hat{i} = -\hat{k} \quad \hat{k}\times\hat{j} = -\hat{i} \quad \hat{i}\times\hat{k} = -\hat{j}$

$\hat{i}\times\hat{i} = \hat{j}\times\hat{j} = \hat{k}\times\hat{k} = 0$

$\vec{A}\cdot\vec{B} = AB\cos\theta \qquad |\vec{A}\times\vec{B}| = AB\sin\theta$

$W = \vec{F}\cdot\Delta\vec{r} \qquad W = \int F_x\,dx$

$P_{avg} = W/\Delta t \qquad P_{avg} = \Delta E/\Delta t \qquad P = \vec{F}\cdot\vec{v}$

$K = \tfrac{1}{2}mv^2 \qquad U_g = mgy \qquad U_s = \tfrac{1}{2}kx^2$

$C = 2\pi R$

Roots of $ax^2 + bx + c = 0$ are:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\frac{d(At^n)}{dt} = nAt^{n-1}$$

For constant $\alpha$

$$\omega = \omega_0 + \alpha t$$
$$\theta = \theta_0 + \omega_0 t + \tfrac{1}{2}\alpha t^2$$
$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$$

$F_{\text{spring}} = -kx$

$W_{\text{by spring}} = \tfrac{1}{2}kx_0^2 - \tfrac{1}{2}kx_f^2$

$E_{\text{mech}} \equiv K + U$

$\Delta K = K_f - K_i = \sum W_{\text{other forces}} - f_k d$

$W_{\text{by cons. force}} = -\Delta U = -(U_f - U_i)$

$-f_k d = \Delta K + \Delta U = \Delta E_{mech}$

$\Delta E_{\text{int}} = f_k d$

$F_x = -\dfrac{dU}{dx}$

$\vec{p} = m\vec{v} \qquad \tau = |\vec{r}\times\vec{F}| = rF\sin\theta$

$\vec{I} = \Delta\vec{p} \qquad L = I\omega = |\vec{r}\times\vec{p}| = rp\sin\theta$

$\sum F_{\text{external}} = \dfrac{d\vec{p}_{\text{total}}}{dt}$

$\vec{r}_{\text{c of mass}} = \dfrac{\sum m_i\vec{r}_i}{\sum m_i} = \dfrac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots + m_N\vec{r}_N}{m_1 + m_2 + \cdots m_N}$

$I = \sum_i m_i r_i^2 = m_1 r_1^2 + m_2 r_2^2 + \cdots m_N r_N^2$

$K_r = \tfrac{1}{2}I\omega^2 \qquad v = r\omega \quad a = r\alpha$

$I = I_{\text{c of mass}} + MD^2 \qquad L = I\omega \quad L = mvd$

$\sum \tau = I\alpha \qquad f = 1/T = \omega/(2\pi)$

$T = 2\pi\sqrt{m/k} \qquad T = 2\pi\sqrt{L/g}$

$x(t) = A\cos(\omega t + \phi)$

$v(t) = -\omega A\sin(\omega t + \phi) \qquad T = 2\pi\sqrt{I/mgd}$

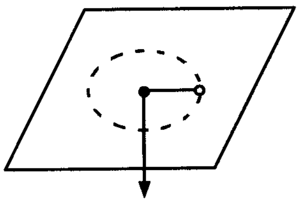
$a(t) = -\omega^2 A\cos(\omega t + \phi)$

For office use only:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | total |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

1. (a) A puck on a frictionless air hockey table has a mass of $5.00\times10^{-3}$ kg and is attached to a cord passing through a hole in the surface as in the figure shown. The puck is revolving at a distance 2.00 m from the hole with an angular velocity of 3.00 rad/s. The cord is then pulled from below, shortening the radius to 1.00 m.

   (i) What is the initial moment of inertia of the puck?
   (ii) What is its initial angular momentum?
   (iii) What is its final moment of inertia (after the cord is pulled)?
   (iv) What is the final angular velocity of the puck in rad/s?
   (v) Calculate the change in the kinetic energy of the system.



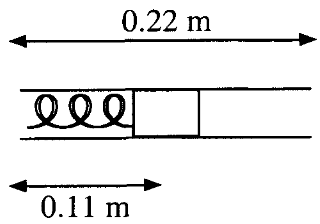
(b) The velocity of a 2.00 kg body moving in the *xy* plane is given by $\vec{v} = (7.00\hat{i} - 2.00\hat{j})$ m/s. Its position vector is $\vec{r} = (2.00\hat{i} - 1.00\hat{j})$ m. Calculate its angular momentum (magnitude and direction) about the origin in (kg m$^2$/s). Express your answer in unit vector notation.

For office use only:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | total |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

2. A gun that shoots corks of mass 0.00460 kg uses a spring of spring constant 10.8 N/m. The 0.220 m long spring is compressed to 0.110 m. Its 0.220 m long barrel exerts a constant force 0.250 N force of friction on the cork when the gun is fired. The spring obeys Hooke's Law. The gun is released and the cork is projected horizontally.

   (a) How much elastic potential energy is stored in the compressed spring?
   (b) How much work (due to friction) does the barrel exerts on the cork after the cork is released?
   (c) What is the cork's speed in m/s at the muzzle of the gun? (Hint: Use the generalized Work-Energy Theorem).
   (d) Suppose the gun is placed on the ledge 2.00 m above the ground. How long does it take for the cork to reach the ground?
   (e) How far does the cork travel horizontally?
   (f) Using unit vector notation, what is the cork's velocity just before it lands on the ground?



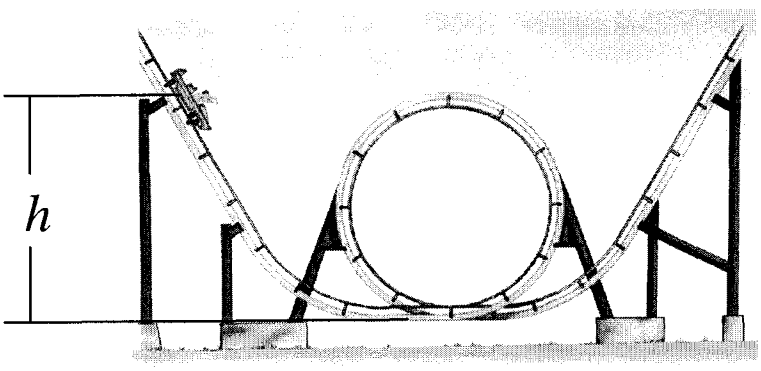
3. A roller coaster car is released from rest at the top of the final rise and then moves freely with negligible friction. The circular loop has a radius $R$. The reference height is taken as the bottom of the loop.

   (a) Suppose the car barely makes it around the loop and at the **top** of the loop the car and the riders are upside down (i.e. the car and riders are in a free fall and the normal force can be set to 0 N at the **top** of the loop). Show that the speed of the car at the **top** of the loop is given by $v_{top} = \sqrt{(Rg)}$.

   (b) Using the conservation of mechanical energy principle show that the required height, $h$, of the release point above the bottom of the loop is given by $2.5R$.

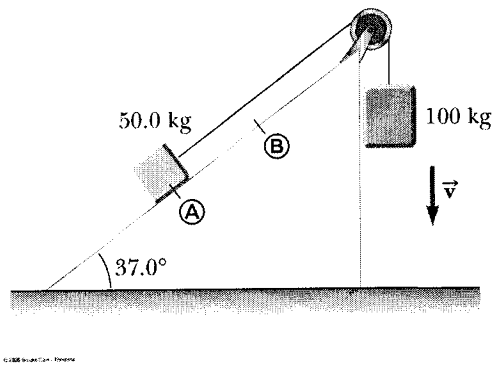
   (c) Given $h$ as obtained in part (b), determine the speed of the car at the **bottom** of the loop ($v_{bottom}$) in term of $R$ and $g$.

   (d) Show that the normal force at the **bottom** of the loop is equal to six times the weight of the car and riders.



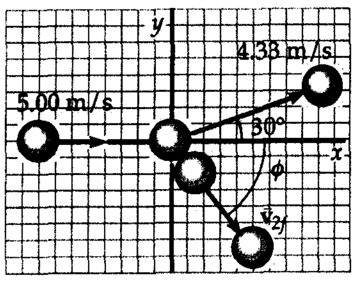
4. Two blocks of mass $m_1$=50.0 kg and $m_2$=100 kg are connected by a string of negligible mass. The pulley is frictionless and also of negligible mass. The coefficient of kinetic friction between the 50.0 kg block and incline is 0.250.

   (a) Draw a free body diagram for the two blocks labeling all the external forces acting on them.
   (b) Determine the tension in the string.
   (c) Find the acceleration of the system.
   (d) Determine the decrease in the **total** mechanical energy of the system (due to the presence of the frictional force) when the 50.0 kg block moves from point A to point B, a distance of 20.0 m.



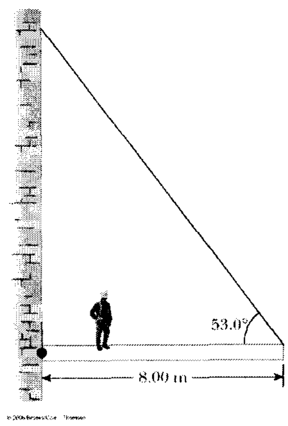
5. A billiard ball moving at 5.00 m/s strikes a stationary ball of the same mass. After the collision, the first ball moves at 4.33 m/s, at an angle of 30.0° with respect to the original line of motion. Assume that the collision is elastic and ignore friction and rotational motion of the balls. The mass of each ball is 0.100 kg.

   (a) What is the velocity of the second ball (its magnitude and direction with respect to the original line of motion) immediately after the collision?
   (b) Express the **final** velocities of the **two** balls in the unit vector notation.
   (c) Calculate the impulse experienced by the second ball during collision.
   (d) Show that the velocity of the center of mass of the two balls after the collision is the same as the velocity of the two balls before the collision.



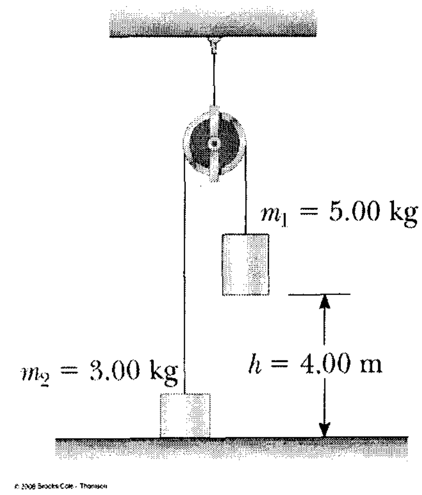
6. A uniform horizontal beam of length 8.00 m and weight 300 N is attached to a wall by a pin connection. Its far end is supported by a cable that makes an angle of 53.0° with the horizontal. A 650 N man stands 2.00 m from the wall.

   (a) Draw a free body diagram showing all external forces acting on the beam.
   (b) Determine the tension in the cable.
   (c) Calculate the components of the force exerted by the wall on the beam at the pivot point.



7. A figure below shows an Atwood machine with a massive pulley. The two blocks of mass $m_1$ = 5.00 kg and $m_2$ = 3.00 kg are connected by a light string that passes over a pulley (modeled as a disk with $I_{CM}=(1/2)MR^2$) of mass $M$ = 10.0 kg and radius $R$=0.300 m. Assume that the frictional torque acting on the bearing of the pulley is negligible and the surface of the pulley is not frictionless so that the string does not slide on the pulley.

   (a) Draw the free body diagrams for each of the three objects (the two masses, $m_1$ and $m_2$, and the pulley) just after the mass $m_1$ is released from rest.
   (b) Calculate the moment of inertia of the pulley.
   (c) Calculate the magnitude of the acceleration of the two objects after the mass $m_1$ is released from rest.
   (d) Determine the speed of the 5.00 kg object just as it hits the ground (note that $m_1$ is 4.00 m above the ground initially).



8. A body, attached to a spring with a spring constant equal to 600 N/m, oscillates with simple harmonic motion along the $x$-axis. Its displacement varies with time according to the equation $x = 5.00 \sin(\pi t + \pi/3)$ where $x$ is in centimeters and $t$ is in seconds. Determine:

   (a) the frequency and the period of the motion,
   (b) the amplitude of the motion,
   (c) the phase constant (note: you may use the identity $\sin(\theta+\pi/2) = \cos(\theta)$),
   (d) the maximum velocity and acceleration,
   (e) the position, velocity and acceleration at $t = 0.250$ s,
   (f) the total mechanical energy of this spring-mass system.

9. An object consists of three point masses ($m_1$ = 0.200 kg, $m_2$ = 0.300 kg and $m_3$ = 0.500 kg) joined by massless rigid rod as shown in the figure below. The masses are located as follows: $m_1$ is at $x_1$ = 0 m, $m_2$ at $x_2$=0.400 m and $m_3$ at $x_3$=0.800 m.

   (a) What is the position, $x_{cm}$, of the object's center of mass?
   (b) The object is pivoted about an axis through the $m_1$ mass so that it can rotate in a vertical circle around that axis as shown. What is the object's moment of inertia about that axis?
   (c) Starting from rest, the object is allowed to swing from horizontal to vertical about the pivot at the $m_1$ mass. By how much does the potential energy of the object change when it goes from horizontal to vertical?
   (d) From the answer to (c) (and (b)), calculate the rotational kinetic energy and the **angular** speed of the object when it is vertical.
   (e) What is the linear speed of the $m_3$ when the object is vertical?
   (f) What is the **angular** acceleration of the object when it is vertical?