PHYSICS 100A
Second Exam (75 minutes, Chapters 7 – 12)
Fall 2007

NAME: _____________________________________  SCORE: ________

Note: All quantities without explicit units are in SI units.

PART I - MULTIPLE CHOICE. EACH QUESTION IS WORTH 5 POINTS FOR A TOTAL OF 40 POINTS.

1. A person applies a constant force of 20 N to a rock of 1000 kg for 20 seconds. What is the work done by this person if the rock does not move at all by this applied force?
   a) 20,000 J
   b) 400 J
   c) 1000 J
   d) 0 J

2. A mass is attached to one end of a string. The other end is attached to a rigid support as shown in the figure. The mass is released at A and swings in a vertical arc to points B, C and D. At what point does the mass have the most potential energy?
   a) A
   b) B
   c) C
   d) D

3. A 1.0 kg mass is pushed against a spring with a spring constant of 25 N/m, compressing the spring a distance of 0.2 m. The mass is then released. What is the kinetic energy of the mass after it is released and is no longer in contact with the spring? Neglect friction.
   a) 5.0 J  From energy conservation:
   b) 0.20 J  \( K_f = U_i = 0.5kx^2 \)
   c) 0.50 J  \[ = 0.5(25 \text{ N/m})(0.2 \text{ m})^2 \]
   d) 10 J  \[ = 0.5 \text{ J} \]

4. Identical forces act for the same length of time on two different masses. The change in momentum of the smaller mass is
   a) larger than the change in momentum of the larger mass.
   b) equal to the change in momentum of the larger mass.
   c) smaller than the change in momentum of the larger mass.
   d) zero.

   The change in momentum equals the impulse which is the same for both masses.
5. A wheel that starts from rest has an angular speed of 20 rad/s after being uniformly accelerated for 10 s. The total angle it has rotated through is
   a) $2\pi$ rad
   b) $40\pi$ rad
   c) 100 rad
   d) 200 rad

6. A figure skater is spinning slowly with arms outstretched. She brings her arms in close to her body and her angular speed increases dramatically. The speed increase is a demonstration of
   a) conservation of energy: her moment of inertia is decreased, and so her angular speed must increase to conserve energy.
   b) Newton’s second law for rotational motion: she exerts a torque and so her angular speed increases.
   c) conservation of angular momentum: her moment of inertia is decreased, and so her angular speed must increase to conserve angular momentum.
   d) conservation of angular momentum: her moment of inertia is increased, and so her angular speed must also increase to conserve angular momentum.

7. The drive chain in a bicycle is applying a torque to the wheel of the bicycle whose moment of inertia is 0.082 kg-m$^2$. The torque imparts an angular acceleration of 10.4 rad/s$^2$ to the wheel. What is the magnitude of this torque?
   a) 0.85 N-m
   b) 1.70 N-m
   c) 127 N-m
   d) 0.0079 N-m

8. What would a woman who weighs 600 N on the earth weigh on a planet that has the same mass as the earth but half its radius?
   a) 150 N
   b) 300 N
   c) 1200 N
   d) 2400 N

From Newton’s Universal Law of Gravitation, $W = \frac{GMm}{r^2}$ where $M$ is the mass of the planet and $r$ is its radius. Since the mass remains the same but the radius is half as large, the new weight is:

$$W' = \frac{GMm}{(r/2)^2} = 4 \frac{GMm}{r^2} = 4(600 \text{ N}) = 2400 \text{ N}$$
PART II - PROBLEM SOLVING. PICK 3 OF FOLLOWING 4 PROBLEMS. IF YOU DO ALL 4, I WILL ONLY GRADE THE FIRST 3 PROBLEMS SO CHOOSE CAREFULLY. EACH PROBLEM IS WORTH 20 PTS FOR A TOTAL OF 60 POINTS.

1) The figure below shows a 0.41 kg block sliding from A to B along a frictionless surface. The kinetic energy of the block at B is 37 J with the heights of A and B being 12 and 7.0 m above the ground respectively.

a) What is the kinetic energy of the block at its starting point A? (8 pts)

From energy conservation,
\[ U_A + K_A = U_B + K_B \]
\[ (0.41 \text{ kg})(9.81 \text{ m/s}^2)(12 \text{ m}) + K_A = (0.41 \text{ kg})(9.81 \text{ m/s}^2)(7 \text{ m}) + 37 \text{ J} \]
\[ \Rightarrow K_A = 17 \text{ J} \]

b) When the block reaches B, it continues to slide along the horizontal surface BC where a kinetic frictional force acts. As a result, the block slows down and comes to rest at C a distance 5.0 m from B. What is the magnitude of the frictional force? (12 pts)

The loss in kinetic energy is due to the work done against the frictional force. That is,
\[ W_{\text{friction}} = -37 \text{ J} \Rightarrow \]
\[ -f_k(5.0 \text{ m}) = -37 \text{ J} \]
\[ f_k = 37 / 5 = 7.4 \text{ N} \]
2) Block 1, of mass $m_1 = 9.90 \text{ kg}$, moves along a frictionless air track with speed $v_1 = 15.0 \text{ m/s}$. It collides with block 2, which was initially at rest. The blocks stick together after the collision and move off with velocity $6.00 \text{ m/s}$.

### a) Find the total initial momentum of the two-block system. (5 pts)

The total momentum before collision is:

$$
P_i = m_1v_{1,i} + m_2v_{2,i}
$$

$$
= (9.90 \text{ kg})(15.0 \hat{x} \text{ m/s}) + 0
$$

$$
= 148.5 \hat{x} \text{ kg m/s}
$$

### b) Find $m_2$, the mass of the second block. (8 pts)

Using conservation of linear momentum,

$$
P_f = P_i \quad \Rightarrow \quad (m_1 + m_2)v_f = 148.5 \hat{x} \text{ kg m/s}
$$

$$
(9.90 \text{ kg} + m_2)(6.00 \hat{x} \text{ m/s}) = 148.5 \hat{x} \text{ kg m/s}
$$

$$
m_2 = 14.85 \text{ kg}
$$

### c) What is the change in the system's kinetic energy due to the collision? (7 pts)

The change in kinetic energy is:

$$
\Delta K = K_f - K_i
$$

$$
= \frac{1}{2}(m_1 + m_2)v_f^2 - \left[ \frac{1}{2}m_1v_{1,i}^2 + \frac{1}{2}m_2v_{2,i}^2 \right]
$$

$$
= \frac{1}{2}(9.90 \text{ kg} + 14.85 \text{ kg})(6.00 \text{ m/s})^2 - \frac{1}{2}(9.90 \text{ kg})(15.00 \text{ m/s})^2
$$

$$
= -668 \text{ J}
$$

The minus sign means there is a loss in kinetic energy.
3) The blade of a lawn mower has a moment of inertia of 4.0 kg·m². Initially, it rotates at 1000 rpm and slows down due to a frictional torque before coming to rest in 30 seconds.

a) What is the initial kinetic energy of the blade? (7 pts)

The initial kinetic energy of the blade is:

\[ K_i = \frac{1}{2} I \omega_i^2 \]

\[ = \frac{1}{2} (4.0 \text{ kg} \cdot \text{m}^2) \left( \frac{1000 \times 2\pi}{60} \text{ rad/s} \right)^2 \]

\[ = 2.19 \times 10^4 \text{ J} \]

b) What is the magnitude of the angular deceleration of the blade? (7 pts)

Using the kinematic equation:

\[ \omega = \omega_0 + \alpha t \]

\[ 0 = \left( \frac{1000 \times 2\pi}{60} \text{ rad/s} \right) + \alpha (30 \text{ s}) \]

\[ \alpha = -3.49 \text{ rad/s}^2 \]

Thus, the magnitude of the angular deceleration is 3.49 rad/s².

c) What is the average power of the frictional torque? (6 pts)

The work done by the frictional torque is equal to the change in kinetic energy. Thus the average power of the frictional torque is:

\[ P = \frac{\text{Work}}{\text{time}} = \frac{|\Delta K|}{t} \]

\[ = \frac{2.19 \times 10^4 \text{ J}}{30 \text{ s}} \]

\[ = 730 \text{ W} \]
4) A 20 kg child sits 2.0 m from the axis of rotation of a seesaw. A second 30 kg child is placed on the same seesaw so that the seesaw is balanced. Take the seesaw to be a uniform plank with mass 10 kg and the axis of rotation to be at its center.

a) Draw a free body diagram for the seesaw showing all forces acting on it. (7 pts)

b) Where should the second 30 kg child sit? (7 pts)
For equilibrium, the net torque is zero. Take torque about the axis of rotation. Then,
\[ (20g)(2 \text{ m}) - (30g)(x) = 0 \]
\[ x = \frac{4}{3} \text{ m} \]

c) What is the force (magnitude and direction) exerted by the axis on the seesaw? (6 pts)
Also, for equilibrium, the net force must equal zero. That is,
\[ N - 10g - 20g - 30g = 0 \]
\[ N = 60g \]
The force exerted by the axis on the seesaw is 60g N in the upward direction.