2^{nd} **Midterm - December 14, 2008**

Name and Surname:
Student ID:
Department:
Signature:

Instructions: In each of the question, explain why you do each step. The questions might contain unnecessary information. If the question does not contain sufficient information, make any necessary assumptions. If you make unnecessary assumptions, you will lose points.

Discussion:

(Explain in your own words. You will lose 2 points for each mathematical relation that you write.)

1. When you are riding a bicycle, you should have realized that the bicycle is quite stable. But if the bicycle is standing still, it is not stable and you will most probably fall to the ground. Explain why a running bicycle is more stable with respect to falling down then a stationary bicycle? (15 points)

2. Consider a (any) phenomenon that you observe in everyday life. Write down this phenomenon and a question based on this phenomenon (10 points). Solve your question (the point that you get for your question).

Short Questions:

3. In a car, the net torque delivered to a wheel by the motor has a magnitude $\tau = 5Nm$. If the mass of the wheel is 20 kg, its moment of inertia 4 kgm^2, its radius 20 cm, what is the acceleration of the car? (Assume that the mass of the car is 1000 kg) (5 points)

4. A mass of 0.8 kg that has a velocity 1.3 m/s hits another mass of 2.2 kg which is initially at rest. If they stick together after the collision, what is their final velocity? (5 points)

5. In nature, there are three dimensional fundamental constants. $\hbar$ (pronounced *h bar*) which has the dimension of angular momentum and has the value: $\hbar = 1.05 \times 10^{-34}\ Js$, the speed of light $c = 3.00 \times 10^8\ m/s$ and the Gravitational constant: $G_N = 6.667 \times 10^{-11}\ Nm^2/kg^2$. Using only these constants, derive a quantity that has the dimensions of mass. Using that the mass of a proton is $m_p = 1.67 \times 10^{-27}\ kg$, how many proton masses does that make? (5 points)

Explicit Calculation:

6. Consider a pulley of mass M in the shape of a cylinder of radius R. A massless rope is wound around the cylinder and at the end of the rope, a

mass m is attached. As the mass is let free to accelerate under gravity, what is its acceleration? (15 points)

7. Our unfortunate lover, is still running away. Realizing that his plans to go to the moon will not work, he passes the cannon and arrives at a bridge over a frozen river. As he is passing over the bridge, it collapses and he finds himself on the ice facing towards the direction that he arrived, i.e. he is facing the father who is trying to reach him. He wants to change his orientation so that he wants to face the exactly opposite direction. How can he do that? Make an estimate of how long it will take him to rotate by 180 degrees. (15 points)

8. In a model of the electron, the electron is treated as a small rotating sphere that has a radius $r_e = 2.818 \times 10^{-15}\ m$. Given that the mass of the electron is $m_e = 9.1 \times 10^{-31}\ kg$, its angular momentum $L = \hbar/2$, its electric charge $q = -1.6 \times 10^{-19}\ C$, find the velocity of the surface of the electron relative to its center of mass if the electron has a speed $v_e = 1.2 \times 10^5\ m/s$ (15 points)

9. During the game, a football player hits a ball horizontally. The ball starts moving horizontally with a speed v_0. Due to the friction forces between the ground and the ball, the ball starts spinning. The ball moves a distance l before it starts rolling without slipping. Calculate l? What is the work done by friction forces? (*Hint:* The work done by friction forces is not equal to the friction force times l). (20 points)

Useful formulae:

You can use the following formula's without deriving them. For anything else, you need to derive it:

$$\begin{aligned} \vec{F} &= m\vec{a}\ ,\quad \vec{a} = \frac{d\vec{v}}{dt}\ ,\quad \vec{v} = \frac{d\vec{x}}{dt} \\ a_r &= \frac{v^2}{r} \end{aligned} \tag{1}$$

where a_r is the radial acceleration of an object making circular motion on a circle of radius r

$$I = \int dM d^2 \tag{2}$$

where dM is the mass of an infinitesimal volumes and d is the distance from the rotation access.

$$\begin{aligned} dV &= r^2 dr \sin\theta d\theta d\phi \\ &= \rho d\rho d\phi dz \\ &= dx dy dz \end{aligned} \tag{3}$$

where $r^2 = x^2 + y^2 + z^2 = \rho^2 + z^2$, $\cos\theta = z/r$, $\tan\phi = y/x$