University of Toronto
Faculty of Applied Science and Engineering
Final Examination, December 18, 2007
First year -Engineering Science
PHY 180F –PHYSICS I-Mechanics
Exam Type: A
Examiner: Professor H. M. van Driel
Duration: 2 ½ hours

Instructions: Do all 6 questions; all questions are of equal value.
There are 150 possible marks.
Aids permitted: writing/drawing aids and non-programmable calculators.
Mks (SI) units are used throughout; use g = 10 ms^{-2}.

1) In 30 words or less, discuss each of the following (WITHOUT symbols, equations, or graphs).
   i) What is meant by a Galilean transformation?
   ii) Explain whether an object has a unique moment of inertia.
   iii) How must you throw a bowling ball to ensure that it will roll without slipping when it first makes contact with the bowling lane?
   iv) What is meant by a collision between two objects?
   v) What is meant by a force field? *[5 marks each]*

2) With the sun directly overhead, a bee is moving towards a tilted table defined by the plane $x + y + 10z = 5$ where z is taken along the vertical axis and x, y are along perpendicular horizontal axes. Starting from her position on a pole at $t = 0$ the bee has a path $\vec{r} = (1 + t^2)\hat{i} + (-4t + 3)\hat{j} + (1 - t^2)\hat{k}$ until she lands on the table.
   i) When does she land on the table? *[5 marks]*
   ii) Is the velocity of the bee ever perpendicular to the table? *[10 marks]*
   iii) What is the speed of the bee's shadow along the table at any time *t* before she lands? *[10 marks]*

3) Consider a planet in orbit about the sun.
   i) Show in general that the the radius vector from the sun to the planet sweeps out an area at a constant rate (Kepler's 2nd law). *[10 marks]*
   ii) If the planet is in a *circular* orbit of radius *R* show that T^2/R^3 is a constant where *T* is the period(Kepler's 3rd law). *[5 marks]*
   iii) Show that for a planet with mass *m*, $\vec{p} \times \vec{L} - Gm^2M\hat{r}$ is a constant where $\vec{L}$ is the orbital angular momentum of the planet about the sun with mass M >>m, $\vec{p}$ is the linear momentum of the planet, $\hat{r}$ is a unit vector directed from the sun to the planet and *G* is the gravitational constant. *[10 marks]*
   Hint: If a quantity is constant its time derivative is zero.

4) A machine gun is attached at one end of a 10 m long stationary flatcar and fires bullets towards the other end.

i) Determine the average recoil force on the gun if it fires 250 bullets per minute, the mass of each bullet is 20 g, and the velocity of bullets leaving the gun is 1000 m/s. *[10 marks]*

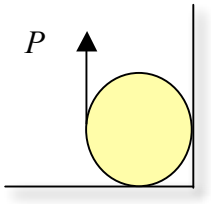
ii) If each bullet is in the 0.5 m long barrel for 2×10^{-3} s, estimate the peak force on the gun. *[5 marks]*

iii) If the bullets are absorbed by a target fixed at the other end of the 10^3 kg flatcar, and the flatcar moves without friction, how fast and in what direction does the flatcar move? *[10 marks]*

5) The figure shows a vertical force applied tangentially to a uniform cylinder of weight F_g. The coefficient of static friction between the cylinder and all surfaces is 0.5.

i) Explain why both friction forces will be at their maximum values when the cylinder is on the verge of slipping. *[10 marks]*

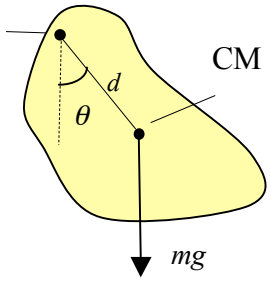
ii) In terms of F_g, find the maximum force P that can be applied without causing the cylinder to rotate. *[15 marks]*



6) Consider the physical pendulum shown below. Represent its moment of inertia about an axis passing through its center of mass (CM) and parallel to the axis passing through its pivot point as I_{CM}.

i) Show that its period for small θ is $T = 2\pi\sqrt{\dfrac{I_{CM} + md^2}{mgd}}$. *[15 marks]*

ii) Show that its period has a minimum value when $md^2 = I_{CM}$. [10 marks]



Total marks = 150