University of Toronto
Faculty of Applied Science and Engineering
Final Examination, December 13, 2006
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 = 9.8 ms^{-2}.

1) In 3 sentences or less, discuss each of the following (WITHOUT symbols, equations, or graphs).
 i) State Kepler's three laws for planetary orbits.
 ii) Describe two different types of fictitious forces that can exist in a non-inertial frame of reference.
 iii) What conditions are necessary for a force to be a conservative force?
 iv) Why does fluid friction on a solid object depend on speed of the object, but kinetic friction between the object and a solid surface does not?
 v) What is meant by the Young's modulus for a material? *[5 marks each]*

2) A rigid system consists of *N* mutually interacting, discrete particles of mass m_1, m_2,…, m_N at positions $\vec{r}_1$, $\vec{r}_2$… $\vec{r}_N$ relative to an origin O. The system is subject to *P* external forces $\vec{F}_1$, $\vec{F}_2$…, $\vec{F}_P$ which are applied at $\vec{R}_1$, $\vec{R}_2$, …. $\vec{R}_P$. Starting from Newton's law for particles, derive an expression for i) the translational acceleration of the centre of mass and ii) angular acceleration about the centre of mass if $\vec{F}_1$… $\vec{F}_P$ and $\vec{R}_1$ …. $\vec{R}_P$ all lie in a plane containing the center of mass. *[12.5 marks each]*

3) A 5 kg bowling ball of radius 0.1 m is thrown up a plane inclined at 30^0 to the horizontal with an initial velocity of 10 m/s. The ball starts from the bottom and initially (*t = 0*) moves in translation only. Because of friction it starts to rotate. The coefficients of kinetic and static friction are 0.5 and 1.0, respectively.

 i) What is the maximum distance the ball travels up the incline? *[9 marks]*
 ii) What is the ball's speed when it returns to the bottom of the incline and how much translational kinetic energy is lost in the round trip? *[8 marks]*
 iii) What is the maximum angle of the incline that will allow the ball to roll down it without slipping, when the ball is released from rest? *[8 marks]*
 Hint: $I = 2/5\ mR^2$

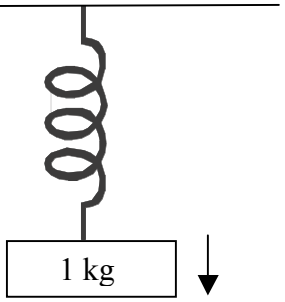
4) A massless spring of spring constant k = 100 N/m and equilibrium length 0.1 m is hung vertically. A 1 kg mass is attached to the end of the spring and released at $t = 0.5$ s.

i) What is the amplitude of the subsequent simple harmonic motion? *[9 marks]*

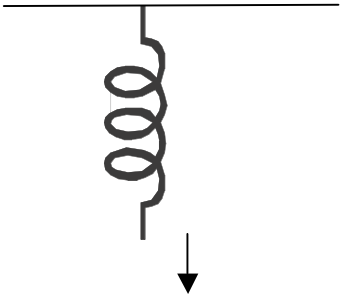
ii) What is the speed of the mass at t = 0.75 s? *[8 marks]*

iii) If the spring has uniformly distributed mass m = 0.1 kg, show that, with no mass attached, the spring's angular oscillation frequency is $\sqrt{3k/m}$ when it is displaced from equilibrium. *[8 marks]*

i), ii)



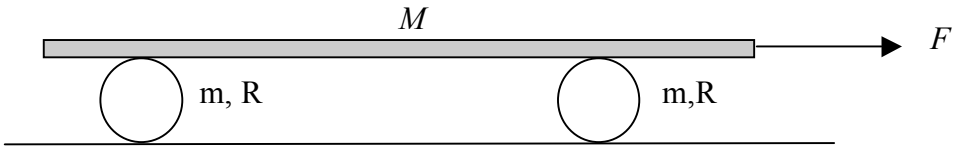
iii)



5) A plank with a mass M = 6.0 kg rides on top of two identical solid cylinder rollers that have R = 0.05 m and m = 2.0 kg. The plank is pulled by a constant horizontal force F of magnitude 6.0 N applied to the end of the plank and perpendicular to the axes of the cylinders (which are parallel to each other). The cylinders roll without slipping on a flat surface. There is also no slipping between the cylinders and the plank.

i) Find the acceleration of the plank and of the rollers. *[12 marks]*

ii) What are the magnitudes of the friction forces that are acting? *[13 marks]*



Hint: $I = 1/2\ mR^2$

6) A comet of mass 1.2×10^{10} kg moves in an elliptical orbit around the Sun. Its distance from the Sun ranges between 0.5 AU and 50 AU.

i) What is the eccentricity of its orbit? *[8 marks]*

ii) What is its period? *[10 marks]*

iii) At aphelion (furthest distance from sun) what is the potential energy of the comet-sun system? *[7 marks]*

Hint: $G = 6.6 \times 10^{-11}$ mks units; $M_{sun} = 2 \times 10^{30}$ kg; 1 AU= 1.5×10^{11} m

Total marks = 150