1^{st} **Midterm - November 4, 2007**

Name and Surname:
Student ID:
Department:
Signature:

Each question worth 10 points. You should show your work. You will lose points if you do not put the right units and put the vector signs for vectors.

Discussion:

1. What are the Newton's three laws of dynamics? Discuss in detail using words only. (You will lose 2 points for each mathematical relation that you write.)

2. When we were discussing in the class that if you hold a book in your hand and walk, your hand does not do any work on the book since the force is perpendicular to the displacement. But you would nevertheless get tired. Why do you get tired if you are not doing any work?

Short Questions:

3. What is the unit of velocity? energy? work? in SI units.

4. If the position of an object as a function of time t is given by:

$$\vec{r} = (0.5m)\hat{x} + (0.9m/s)t\hat{y} + (3.5m/s^2)t^2\hat{z} \tag{1}$$

what is the velocity of the object as a function of time? what is the acceleration? Describe a system in which if you let the particle free, the position of the particle as a function of time will be describe by this equation.

Explicit Calculation:

5. Calculate the gravitational potential energy of a solid sphere of mass M and radius R. (*Hint:* You might consider the sphere as consisting of concentric shells added one after the other.)

6. The unlucky lover(of the homework), eventually gets the attention of his girlfriend. (Then you might ask why he is unlucky) But he also gets the attention of the father of his girlfriend, who starts chasing the boy. Trying to get advantage of his youth, he starts climbing the hill nearby at a constant speed of v_b. The angle that the hill makes with the ground

has a constant value of α. When the angry father reaches the start of the hill, the boy is already a distance d away. Since the hill is too steep for the man, he considers throwing a stone to the boy. If the maximum speed with which he can throw the stone is v_0, what is the range(measured along the hill) of the stone that he can throw as a function of the angle with which he throws the stone and the slope of the hill. What is the maximum range? What is the maximum distance d such that if d is less than that, the father has a chance to hit the boy?

7. Two trains A and B are moving towards each other at velocities relative to ground v_A and v_B respectively. At the instant that the distance between the trains is R, a bird starts flying from train A towards train B with a velocity v relative to the ground. The moment it reaches the other, it turns around and flies to train B with the same speed. Calculate the time elapsed between its departure and arrival to the train A. (*Hint:* Use a reference frame in which one of the trains is at rest. Note that in this reference frame, the speed of the bird is not the same in both directions)

8. Our unfortunate lover is still trying to run away from the father of the girlfriend. Little by little he is getting desperate that he can get away from him. He arrives at a river which is 40 m wide, and there is a boat resting on the side of the river. In still water he can row with a speed of 30 m/s. The river is running at a speed of 20 m/s. He has to cross the river and reach the point directly across him. What should be the angle between his rowing direction and coast of the river so that he can reach the other point? How long does it take him to reach the other end?

9. When our unfortunate lover reaches the other side, he realizes that the father had taken the other boat to cross the river. As he is trying to find another way to escape, he notices a space cannon which can launch a space capsule with a velocity v. If after being launched, there is no propulsion, what should be the minimum speed v such that the capsule can reach moon? (Let the mass of the moon and the earth be m and M respectively, and the distance between the two R. Let m_c be the mass of the capsule. Ignore friction effects.)(Unfortunately, the velocity of the capsule is too slow.To be continued...)

10. Consider a mass attached at the end of a rope which is being rotated vertically. Let the velocity of the mass be v at the topmost position. Calculate the tangential and centripetal acceleration of the mass as a function of the angle, θ, the rope makes with the vertical. What is the tension on the rope as a function of θ? What is the minimum speed v such that the mass can make circular motion?

Usefull formulae:

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

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

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