Spring 2016 Physics 7A Lec 001 (Yildiz) Midterm II

1. (15 points) An object is released from rest at an altitude *h* above the surface of the Earth. *h* is comparable to the radius of Earth (R_E), so gravitational acceleration (g) is not constant.

a) What is the velocity of the object when it hits the surface of Earth?

b) What is the gravitational acceleration of the object at distance *r* from the Earth's center, where $R_E < r < R_E + h$?

c) What is the rate of change of the gravitational acceleration $g(r)$ as a function of the distance *r* from the Earth's center, where $R_E < r < R_E + h$?

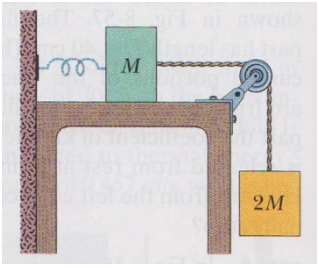
2. (20 points) Assume a cyclist of weight *mg* can exert a force on the pedals equal to 0.80 *mg* on the average. The pedals rotate in a circle of radius 18 cm, the wheels have a radius of 34 cm, and the front and back sprockets on which the chain runs have 42 and 19 teeth respectively. The mass of the bike is 14 kg and that of the rider is 63 kg. Assume there is no slipping between the ground and the wheel. Use g = 10 m/s^2 for calculations.

a) How is the angular velocity of the rear wheel of a bicycle related to the angular velocity of the front sprocket and pedals? The teeth are spaced the same on both sprockets and the rear sprocket is firmly attached to the rear wheel.

b) Determine the maximum steepness of hill the cyclist can climb at constant speed. Assume the cyclist's average force is always *tangential* to pedal motion.

c) Determine the maximum steepness of hill the cyclist can climb at constant speed. Assume the cyclist's average force is always *downward*.

3. (20 points) Two block of masses *M* and *2M* are connected to a spring of spring constant *k* that has one end fixed, as shown. The horizontal surface and the pulley are frictionless and the pulley has negligible mass. The blocks are released from rest with the spring relaxed.

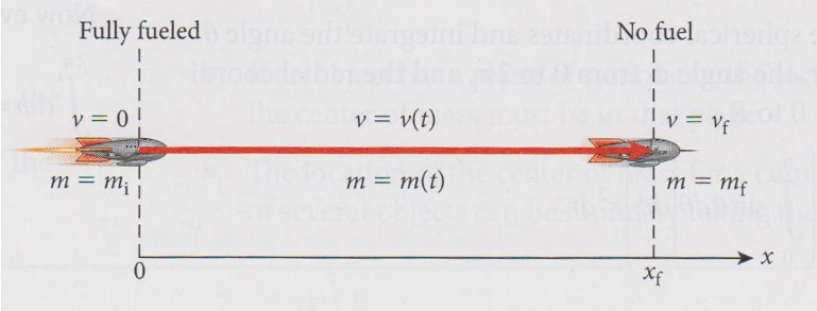


a) What is the velocity of the blocks when the hanging block has fallen a distance *h*?

b) What maximum distance h_{max} does the hanging block fall before momentarily stopping?

c) In the absence of friction, the system is expected to oscillate back and forth infinitely. However, if there is kinetic friction between block and the horizontal surface (coefficient of kinetic friction is μ_k), the system will eventually come to a complete stop. What is the equilibrium position of the spring's extension when the system comes to a complete stop? What is the total distance traveled by the hanging block before the system comes to a complete stop? (Assume that the frictional force on the mass *M* on the horizontal surface is negligible when the system comes to a complete stop.)

4. (25 points) Suppose a spacecraft with initial mass of m_i. Without its propellant, the spacecraft has a mass of $m_f = m_i/3$. The rocket that powers the spacecraft is designed to eject the propellant with a speed of u relative to the rocket at a constant rate of R. The spacecraft is initially at rest in space and travels in a straight line.



a) How long would it take the rocket to release all of its propellant?

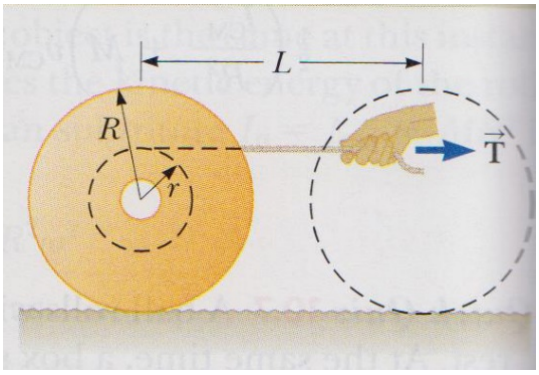
b) What is *m(t)*, the mass of the rocket as a function of time?

c) What is *v(t)*, the speed of the rocket as a function of time?

d) How far will the spacecraft travel before its rocket uses all the propellant and shuts down?

Hint: $\int \ln(1-ax)\,dx = \frac{ax-1}{a}\ln(1-ax) - x$

5. (20 points) A cylindrically symmetric spool of mass m and radius R sits at rest on a horizontal table with friction. With your hand on a massless string wrapped around the axle of radius r, you pull on the spool with a constant horizontal force of magnitude T to the right. As a result, the spool rolls without slipping a distance L along the table. Assume that the spool is a solid uniform cylinder.



a) What is the distance that you hand travels as the spool moves a distance L?

b) Find the final translational speed of the center of mass of the spool using the work-energy principle?

c) Find the value of the friction force f and acceleration of the spool using the equations for dynamics of the motion (e.g. force and torque)?