PHYSICS 7A – Spring 2010
Final Exam
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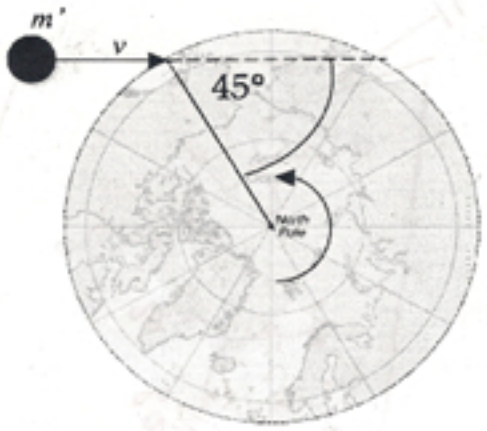
Problem 1 (30 points)

The Earth has a radius of $r = 6400$ km and the acceleration of free fall at the surface is $g = 9.8$ m/s^2. Assume it is a solid sphere of constant density. (The moment of inertia of such a sphere is $2mr^2/5$).

a) What is the Earth's mass m? The Newtonian constant of gravitation is $G = 6.67\times10^{-11}$ m^3/(kg s^2).

b) What is the moment of inertia I of the Earth?

c) Suppose a $m' = 5.8\times10^{10}$ kg meteorite (of negligible radius) struck the Earth as shown below with a speed of $v = 2.2\times10^4$ m/s and remained stuck. By what factor would this affect the rotational frequency of the Earth (1 rev/day)?



Problem 2 (20 points)

A table ($M = 10$ kg) is sitting on four equal springs. A $m = 0.8$ kg chunk of modeling clay is held above it and dropped so it hits the table in the middle with a speed of $v = 1.65$ m/s and immediately afterwards sticks to the table. After a long time, the table comes to rest $d = 6.0$ mm below its original position.

a) What is the combined spring constant of the four springs?

b) With what maximum amplitude did the platform oscillate?

c) What is the instantaneous velocity of the table 1.0s after impact? Neglect friction.

Problem 3 (15 points)

A ski gondola is connected to the top of a hill by a steel ($\rho = 7.8\times10^3$ kg/m^3) cable of length $l = 700$ m and diameter $d = 1.5$ cm. As the gondola comes to a stop at the end of its run, it bumps into the terminal and sends a wave pulse along the cable. It is observed that it took $\Delta t = 18$ s for the pulse to return.

a) What is the speed of the pulse?

b) What is the tension in the cable?

Problem 4 (20 points)

The e"-string of a violin has a vibrating length of 330 mm, is made of steel ($\rho = 7.8 \times 10^3$ kg/m^3), and resonates at a fundamental frequency of $f_0 = 660$ Hz.

a) If this string can be tuned to 800 Hz before it snaps, what is the tensile strength (force/area) of this particular steel string? (Turns out that this is very high tensile strength steel)

b) If one such violin is played on the podium of a symphony hall and measured by someone in the audience to produce a sound volume of 75 dB, what is the sound volume measured, in dB, for the 32 violins of a large symphony orchestra, if they are all played alike?

c) A kettle drum is struck with a stick that has a mass of 0.2 kg and a velocity of 10 m/s. Within 20 ms, 10% of the stick's kinetic energy is converted into a "bang." What is the intensity of that sound in dB at a distance of 10 m, if the sound level is constant over the 20 ms?

Problem 5 (15 points)

When a car passes by, the pitch of the engine is heard to be higher when the car is approaching and lower when it passed.

a) Express the frequency ratio (f_{before} / f_{after}) in terms of the velocity of sound ($v_s = 340$ m/s) and the velocity of the car, v.

b) If someone is able to discern a frequency change that corresponds to half of a semitone, *i.e.*, 1.03:1, what is the minimum speed of the car that would produce an audible frequency change?

Problem 6 (20 points)

a) The speed of blood flow in a particular artery in a healthy person is $v = 0.3$ m/s. Suppose the artery is partly constricted (over all of its length) to 0.8 of its original radius. How much does this increase the velocity of the blood stream v if the heart pumps harder to maintain the same mass flow rate?

b) A model airplane has a mass of $m = 2.5$ kg and a wing surface area of $A = 0.5$ m^2. The wing shape is such that the air stream over the top of the wing is 20% faster than the airspeed of the plane. The speed of the air stream across the bottom of the wing is approximately equal to the plane's airspeed. What is the minimum airspeed for the plane in order to stay airborne? Use $\rho = 1.29$ kg/m^3 for the density of air.