PHYSICS 7A – Spring 2010
Midterm 2, H. Mueller

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Problem 1 (15 points)

A pumped-storage hydroelectricity plant consists of an upper lake that is elevated 350 m relative to the lower lake. A volume of 1.1×10^6 m^3 of water (density 1.0×10^3 kg/m^3) can be taken out of the upper lake. This water volume supports 1.0 hour of full load operation. The acceleration of gravity is 9.8 m/s^2.

a) How much electrical power does the plant produce, assuming an efficiency η=0.85 for the conversion of the water's gravitational potential energy to electrical energy?

b) At nighttime, the upper lake is replenished by pumping the water back. How long does this take if an electrical power of 150 MW is available, and the efficiency of the pumping is η=0.85?

c) What is the overall efficiency of the plant for storing electrical energy?

Problem 2 (15 points)

Earth's radius is 7,000 km and the acceleration of gravity near the surface is g=9.8 m/s^2.

a) What is the velocity v of a satellite (of mass m) orbiting just above ground? This velocity needs to be provided by the launch rocket. What is the kinetic energy of the satellite?

b) To make the launch easier, the satellite is launched at the equator. How much does this reduce the required velocity? By how much does this reduce the kinetic energy (measured relative to the launch pad), as expressed as a percentage of the energy needed in a)? [Hint: What is the velocity of the rocket, relative to the center of the earth, when it is just sitting on the equator?]

c) The acceleration of gravity g_m on the moon is 1/6 the one on earth. If the moon's density is the same as Earth's, what is its radius?

Problem 3 (20 points)

A grandfather clock's pendulum consists of a rigid rod of length l=1.100 m and mass m=1.000 kg to which a mass M of 5.000 kg (of negligible size) is attached. The pendulum is free to rotate around the upper end of the rod. The distance of M from that point is l_M =1.021 m. (The moment of inertia of a rod for rotation around its center is $Ml^2/12$).

a) What is the moment of inertia I of the pendulum?

b) Where is the center of mass, as expressed by its distance l_{cm} from the top of the rod?

c) The pendulum is deviating from the vertical by a small angle φ. What is the torque due to gravity as function of φ? Use $\sin\varphi\approx\varphi$ for angles φ that are much lower than 1.

d) Express the angular acceleration $\alpha=\mathrm{d}^2\varphi/(\mathrm{d}t)^2$ of the pendulum as a function of φ. Now insert the *ansatz* (i.e., guessed solution) $\varphi(t)=A\sin[(2\pi/T)t]$, where A and T are constants. Determine T. Sketch $\varphi(t)$. What is the significance of T?

Problem 4 (15 points)

An SUV (type H-2) has a mass of m=3000 kg. It has a width of w=2062 mm and its center if mass is h_{CM}=950 mm above ground and in the middle between the wheels. The maximum engine power is P=293 kW (which is equivalent to 393 hp).

a) How long will it take the car to accelerate from 0 to 60 mph at maximum engine power? (1 mph is about 0.44 m/s)

b) The car is driving at a velocity of 25 m/s and is making a turn of radius r. What is the torque τ around an axis going through the outer wheels produced by the centrifugal force, as function of r?

c) At 25 m/s, what is the minimum radius before the car begins to top over? Assume that the wheels do not slip.

Problem 5 (20 points)

Big car (M=2400kg) is moving with a velocity of 20 mph in x-direction and crashes into small car (m=1200 kg) which is moving in y-direction, orthogonally to big car, with 20 mph. The collision is completely inelastic.

a) Calculate the x- and y- velocity of the center of mass.

b) What's the total kinetic energy (sum of both cars) in the rest frame and the center of mass frame before and after the collision?

c) What is the speed in x and y direction of the cars after collision?

d) Assuming the collision takes 50 ms, what is the magnitude of the acceleration experienced by the drivers of both cars?

Problem 6 (10 points)

You (m=90 kg including the bike and heavy books) are riding your bike on a designated bicycle route, which has a stop sign every 250 m, in the city of Berkeley. Before each stop sign, you stop (neglect the time it takes to break). Then, you immediately accelerate, producing a power of 250 W until you have to start breaking at the next stop sign.

a) How long will it take you to ride this road for 1.0 miles? Neglect friction and air resistance.

b) Assuming the coefficient of friction (including air resistance) is 0.05, what power will you need to ride for 1.0 miles in the same time (at a constant velocity) if there are no stop signs?