Physics 105a-2008 Practice Problems for Exam

IMPORTANT: This is not a full-length practice exam. Instead, it is a set of questions intended to give you a sense of the style of questions you may find on the actual exam. Of course, the actual exam questions will not be on exactly the same topics as these questions. Therefore, if you do well on these questions, that does not necessarily mean that you have prepared adequately for the real exam. However, if you do poorly on these questions, that does indicate that you need to review the associated material more thoroughly. Also, you may find the problems on the actual exam to be harder or easier than these problems. You should be able to complete each of these problems, including all sub-parts, in about fifteen minutes.

1. In normal driving, the relevant coefficient of friction between the tires and the road is $\mu_s$, because the bottom part of the tire moves backward at the same speed as the road moves backward (as seen in the frame of the driver). Thus, there is no relative motion between the road and the part of the tire touching the road, so the friction is static.

   In a drag racing car, the engine supplies power only to the rear wheels. However, only part of the weight is supported by these wheels – part is also supported by the front wheels. The engines are enormously powerful – by stepping on the gas all the way, a driver can easily exceed the force of static friction between the tires and the road, so that the wheels “spin” and there is relative motion between the bottom of the tire and the road, causing a great deal of squealing and smoke.

   a) Explain why good drag racers try to avoid this, and instead step on the gas as much as they can without “spinning” the wheels like this.

   b) If the total mass of the care and driver is $M$, the weight supported by the rear wheels is $mg$ (which is less than $M$), the coefficient of static friction is $\mu_s$, the coefficient of kinetic friction is $\mu_k$, and the radius of the rear wheels is $r$, what is the minimum time it takes for a skillful driver to go a distance $D$, starting from rest. Assume the engines are extremely powerful, so that the engine power is not a limiting factor. Also assume the “rolling friction” from the front wheels is negligible.

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3. A resourceful undercover U.S. spy has made her way into the embassy of Elbownia, where she has recovered a computer disk just stolen from a U.S. weapons lab; the disk could reveal the secret to vaporizing all coffee in the U.S., leading to massive civil disorder every morning. She races to the window and throws the disk towards an open window in the facing building, where her spy partner awaits. She throws the disk so its initial velocity (shown on the drawing below) has an angle with respect to the horizontal of 10.0° and a speed of 20.0 m/s. (See the drawing for more information.) In answering the following questions, you may assume no wind resistance, modeling the disk as a simple projectile.

(a) (18 points) Does the disk make it through the partner’s window? Express your answer by computing where exactly the disk either enters the window of the facing building, or else hits the building’s outer wall (if it misses the window). Be sure to define all your variables so I know what your answer means.

(b) (7 points) Foreign security forces rush into her room in the embassy 0.65 seconds after the disk leaves her hand. Solve for the coordinates of the disk at the moment the security forces enter the room. (Her cover is still safe if the disk is already inside the facing building!) Again, show your computations.

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4. Two blocks are glued securely together. The upper block has mass $m_A$ and the lower block has mass $m_B$. A rope is affixed to the top block, and tension $T$ is applied. Gravity is also acting. The tension might be greater than, less than, or equal to the total force of gravity. Derive Newton’s third law in this case, starting from Newton’s second law. In other words, show that the force that block A exerts on block B, $F_{AB}$, is equal in magnitude but opposite in direction to the force that block B exerts on block A, $F_{BA}$, i.e. show that $F_{AB} = -F_{BA}$. Of course, you are not allowed to use Newton’s third law in making your argument.

5. (Read the first part of problem 1 before beginning this problem.)

Curves on highways and racetracks are often “banked”, i.e. angled, as shown here:

If the coefficient of kinetic friction is $\mu_k$, the coefficient of static friction is $\mu_s$, the mass of the car is $m$, the banking angle is $\Theta$, and the radius of the curve is $r$, what is the maximum speed $v$ at which the car can go around the curve without slipping? (Assume that $\Theta$ is small enough that friction is needed for the car to negotiate the curve.)

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Problem 6 (18 points—6 points each part) In the picture below, mass \( m_1 \) is hanging on a rope which passes over a pulley and is connected to \( m_2 \), which is sitting on an inclined plane which makes a 30° angle with respect to the horizontal. Assume that the mass slides frictionlessly on the plane. Also, remember that the tension in the rope can be assumed to be everywhere the same. (That is, the pulley is also frictionless.)

(a) For what ratio of values \( \frac{m_2}{m_1} \) can this system be in balance?

(b) If the two masses are actually identical in value, \( m_1 = m_2 = m \), with what acceleration will they move after being released and in what direction? (Give your answer in terms of \( g \).)

(c) Now, still assuming the masses are equal, let's include friction in the problem. Let \( \mu \) be the static coefficient of friction for mass \#2 sliding on the plane. Show that the minimum value of \( \mu \) necessary to keep the masses from starting to move is 0.58.