Homework 9 Solutions
Physics 1000
Preparatory Physics
Due: Friday April 4, 1997

Motion of an Object on a Frictionless Horizontal Plane

1. A 10 kg object rests on a frictionless horizontal plane with no applied forces other than the force of gravity. Choose the coordinate system with origin at the center-bottom of the object such that the positive x-direction is to the right and the positive y-direction is up. (This is the standard coordinate system I always use in class.)

   a. In the space provided directly below, draw the free-body diagram labeling all forces, their directions and their magnitudes, which are applied to the body. Specify units! Label the force of gravity as F_g and the normal force as N, as we did in class.

   Answer: See the final page of the solutions.

   b. Which of Newton's Laws is responsible for the guaranteeing the existence and governing the magnitude of the normal force?

   Answer: Newton's Third Law says that forces always come in pairs. The force of gravity applies a force from the object on the plane. The plane pushes back with an equal and opposite force, the normal force.

2. A 100 N force is applied in the positive x-direction to the object in #1.

   a. In the space provided directly below, draw the free-body diagram labeling all forces and their magnitudes which are applied to the body. Label the applied force as $\mathcal{F}$, as we did in class.

   Answer: See the final page of the solutions.

   b. What is the resulting acceleration of the object? Specify direction and magnitude. Find acceleration in both the x and y directions.

   Answer: $ma_x = \mathcal{F} = 100\ \text{N} \rightarrow a_x = \mathcal{F}/m = 100\ \text{N}/10\ \text{kg} = 10\ \text{m/s}^2$. There are no forces and, hence, accelerations in the y-direction: $a_y = 0$.

Motion of an Object on a Horizontal Plane with Friction

3. The same 10 kg object sits on a horizontal plane where the coefficient of friction is $\mu = 0.4$. Gravity is applied as before. Choose the same coordinate system as in #1 and #2.

   a. In the space provided directly below, draw the free-body diagram labeling all forces and their magnitudes which are applied to the body. Assume that a force of unspecified magnitude, $\mathcal{F}$, is applied in the positive x direction. Label the force of friction as F_f.

   Answer: See the final page of the solutions.

b. A 1 N force is applied to the object in the positive x direction. What is the resulting acceleration of the object? Specify direction and magnitude. Find acceleration in both the x and y directions.

<u>**Answer:**</u> Recall that solutions to problems involving friction divide into two categories: (1) when the applied force is less than the maximum force friction can provide and (2) when the applied force is greater than or equal to the maximum force that friction can provide. So, to do both b. and c. here we need to find the maximum force of friction. $|F_f|_{max} = \mu N = \mu mg = 0.4$ (10 kg) (9.8 m/s^2) = 39.2 N. Now, in the case of this problem, b., the applied force is only 1 N which is less than 39.2 N. The applied force cannot overcome the force of friction, so the object cannot move: $a_x = 0, a_y = 0$.

c. A 200 N force is applied to the object in the positive x direction. What is the resulting acceleration of the object? Specify direction and magnitude. Find acceleration in both the x and y directions.

<u>**Answer:**</u> If the applied force is 200 N, however, the applied force can overcome friction and will accelerate the object in the positive x-dirction. $ma_x = \mathcal{F} + F_f = \mathcal{F} - \mu mg =$ 200 N - 0.4(10 kg)(9.8 m/s^2) = 160.8 N $\rightarrow a_x =$ 160.8 N/m = 160.8 N/10 kg $\sim$ 16.1 m/s^2.