PHYSICS 2020
Homework #5

(Due October 27, 2026, 6:00 pm)

Show all work. Include appropriate units with all numerical answers. Give numerical answers to three or four significant figures unless otherwise indicated. Use $g = 9.8\ \mathrm{m/s^2}$ unless otherwise specified.

1. A horizontal force of 24.0 N acts on a 6.00 kg object initially at rest on a frictionless horizontal surface.

(a) Find the acceleration of the object.

(b) Find its velocity after 5.00 s.

(c) How far does it travel during this time?

2. A 12.0 kg box rests on a frictionless inclined plane that makes an angle of 30.0° with the horizontal.

(a) Draw a free-body diagram showing all forces acting on the box.

(b) Find the component of the gravitational force parallel to the inclined plane.

(c) Find the normal force exerted by the plane.

(d) Find the acceleration of the box after it is released.

3. A traffic light having a mass of 18.0 kg hangs motionless from two cables. The left cable makes an angle of 35.0° above the horizontal, and the right cable makes an angle of 55.0° above the horizontal.

(a) Draw a free-body diagram of the traffic light.

(b) Write the equations for equilibrium in the horizontal and vertical directions.

(c) Find the tension in each cable.

4. A 20.0 kg wooden crate rests on a horizontal floor. The coefficient of static friction between the crate and the floor is $\mu_s = 0.450$, and the coefficient of kinetic friction is $\mu_k = 0.300$.

(a) Find the maximum possible static friction force.

(b) A horizontal force of 60.0 N is applied to the crate. Does the crate move? Explain.

(c) The applied horizontal force is increased to 120 N. Find the acceleration of the crate after it begins moving.

5. A small sphere of mass 0.250 kg falls vertically through a fluid. The fluid exerts a resistive force opposite to the direction of motion, with magnitude

$$F_r = -bv,$$

where $b = 0.500\ \text{kg/s}$ and v is the speed of the sphere. Neglect buoyancy.

(a) Draw a free-body diagram of the sphere while it is falling.

(b) Write Newton's second law for the sphere, taking downward as positive.

(c) Find the terminal speed of the sphere.

(d) Find the acceleration of the sphere when its downward speed is 3.00 m/s.

6. A car of mass 1200 kg travels at a constant speed of 15.0 m/s around a level circular curve of radius 60.0 m.

(a) Find the centripetal acceleration of the car.

(b) Find the magnitude of the net horizontal force acting on the car.

(c) Assuming that static friction between the tires and the road provides the centripetal force, find the minimum coefficient of static friction needed to prevent skidding.

(d) If the car doubles its speed, by what factor does the required centripetal force change?

7. A worker pulls a 25.0 kg box across a horizontal floor through a distance of 8.00 m. The worker applies a constant force of 100 N at an angle of 30.0° above the horizontal. The coefficient of kinetic friction between the box and the floor is $\mu_k = 0.200$.

(a) Find the normal force acting on the box.

(b) Find the work done by the applied force.

(c) Find the work done by friction.

(d) Find the total work done on the box.

8. A 2.00 kg block is released from rest at the top of a frictionless ramp. The block begins at a height of 5.00 m above the bottom of the ramp.

(a) Find the initial gravitational potential energy of the block, taking the bottom of the ramp as the zero of potential energy.

(b) Find the kinetic energy of the block when it reaches the bottom of the ramp.

(c) Find the speed of the block at the bottom.

(d) Would the final speed change if the mass of the block were doubled? Explain.

9. A 5.00 kg block starts from rest and slides down a rough inclined plane. The plane is 10.0 m long and makes an angle of 30.0° with the horizontal. The coefficient of kinetic friction between the block and the plane is $\mu_k = 0.150$.

(a) Find the work done by gravity as the block slides to the bottom of the plane.

(b) Find the work done by friction.

(c) Use the work-energy theorem to determine the speed of the block at the bottom of the plane.

(d) Calculate the acceleration of the block using Newton's second law, and verify your answer to part (c) using a kinematics equation.

10. Find the Error. A student is analyzing the motion of a 1000 kg car traveling at a constant speed of 20.0 m/s around a level circular track of radius 50.0 m.

The student calculates the centripetal acceleration:

$$a_c = \frac{v^2}{r} = \frac{(20.0)^2}{50.0} = 8.00 \text{ m/s}^2.$$

The student then writes:

$$F_{\text{net}} = ma = (1000)(8.00) = 8000 \text{ N}.$$

The student concludes:

> Since the car is moving at a constant speed, the work done by the centripetal force is
>
> $$W = Fd = (8000)(100) = 800000 \text{ J}$$
>
> when the car travels a distance of 100 m along the circular track. Therefore, the car gains 800000 J of kinetic energy.

(a) Are the student's calculations of centripetal acceleration and centripetal force correct?

(b) Identify and explain the error in the student's calculation of work.

(c) What is the actual work done by the centripetal force as the car travels 100 m along the circular track?

(d) Explain why the car can have a nonzero acceleration while its kinetic energy remains constant.