PHYSICS 2020
Homework #6

(Due November 16, 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 $g = 9.8\ \text{m/s}^2$ unless otherwise specified.

1. A 2.50 kg object is initially at rest at a height of 8.00 m above the ground. It is released and falls freely. Neglect air resistance.

(a) Find its initial gravitational potential energy, taking the ground as the zero of potential energy.

(b) Find its kinetic and potential energies when it is 3.00 m above the ground.

(c) Find its speed at that height.

(d) Find its speed immediately before striking the ground.

2. A 4.00 kg block slides across a horizontal floor with an initial speed of 6.00 m/s. The coefficient of kinetic friction between the block and the floor is $\mu_k = 0.250$.

(a) Find the initial kinetic energy of the block.

(b) Find the magnitude of the frictional force.

(c) Use the work-energy theorem to determine how far the block slides before coming to rest.

(d) Is friction a conservative force? Explain.

3. A 3.00 kg object is lifted vertically from the floor to a height of 2.00 m, then moved horizontally through 5.00 m, and finally lowered vertically back to the floor.

(a) Find the work done by gravity during the upward motion.

(b) Find the work done by gravity during the horizontal motion.

(c) Find the work done by gravity during the downward motion.

(d) Find the total work done by gravity over the complete path.

(e) Explain how your result illustrates a property of conservative forces.

4. An electric motor lifts a 150 kg load vertically through a height of 12.0 m in 8.00 s at constant speed.

(a) Find the work done in lifting the load.

(b) Find the average useful power delivered by the motor.

(c) If the motor is 75.0% efficient, find the electrical power supplied to the motor.

(d) Express the electrical input power in horsepower, using 1 hp $= 745.7$ W.

5. A 1200 kg automobile travels east at 20.0 m/s.

(a) Find the momentum of the automobile, including its direction.

(b) The automobile accelerates to 30.0 m/s east. Find its change in momentum.

(c) If this change occurs in 5.00 s, find the average net force acting on the automobile.

(d) Explain why momentum is a vector quantity while kinetic energy is a scalar quantity.

6. A 0.150 kg baseball is traveling horizontally east at 40.0 m/s. It is struck by a bat and leaves traveling horizontally west at 50.0 m/s.

(a) Taking east as the positive direction, find the initial and final momenta of the baseball.

(b) Find the change in momentum of the baseball.

(c) Find the impulse delivered to the baseball by the bat.

(d) If the bat is in contact with the baseball for 0.00500 s, find the average force exerted on the baseball.

7. Two students stand on skateboards on a frictionless horizontal surface. Student A has a mass of 60.0 kg, and Student B has a mass of 45.0 kg. Initially, both students are at rest. They push against each other and move apart.

After the push, Student A moves west at 1.50 m/s.

(a) Find the total momentum of the system before the push.

(b) Find the velocity of Student B after the push.

(c) Find the total kinetic energy of the two students after the push.

(d) Where did this kinetic energy come from? Explain why conservation of momentum does not require kinetic energy to remain constant.

8. A 2.00 kg object has an initial velocity

$$\mathbf{v}_i = (3.00\mathbf{i} + 4.00\mathbf{j}) \text{ m/s}.$$

A force acts on the object, changing its velocity to

$$\mathbf{v}_f = (-1.00\mathbf{i} + 6.00\mathbf{j}) \text{ m/s}.$$

(a) Find the initial momentum vector $\mathbf{p}_i$.

(b) Find the final momentum vector $\mathbf{p}_f$.

(c) Find the impulse vector $\mathbf{I} = \mathbf{p}_f - \mathbf{p}_i$.

(d) Find the magnitude and direction of the impulse vector.

(e) If the force acts for 0.500 s, find the average force vector.

9. A time-dependent force acts on a 2.00 kg object initially at rest on a frictionless horizontal surface. The force is

$$F(t) = (12.0 \text{ N/s})t$$

for $0 \leq t \leq 4.00$ s, and acts in the positive x direction.

(a) Write an integral expression for the impulse delivered to the object during the 4.00 s interval.

(b) Evaluate the integral to find the impulse.

(c) Use the impulse-momentum theorem to determine the final velocity of the object.

(d) Find the average force acting on the object during this interval.

(e) Explain why multiplying the final force by the elapsed time would give an incorrect value for the impulse.

10. Find the Error. A student is analyzing a 0.200 kg ball that strikes a wall horizontally at 15.0 m/s and rebounds in the opposite direction at 10.0 m/s.

The student calculates the initial and final momenta as

$$p_i = (0.200)(15.0) = 3.00 \text{ kg m/s}$$

and

$$p_f = (0.200)(10.0) = 2.00\ \text{kg m/s}.$$

The student then calculates the impulse:

$$I = p_f - p_i = 2.00 - 3.00 = -1.00\ \text{N s}.$$

The student concludes:

> The wall delivers an impulse of -1.00 N s to the ball. The negative sign indicates that the impulse is directed opposite to the ball's original motion.

(a) Identify the error in the student's calculation.

(b) Taking the initial direction of motion as positive, calculate the correct initial and final momenta.

(c) Calculate the correct impulse delivered to the ball.

(d) If the ball is in contact with the wall for 0.0200 s, find the average force exerted by the wall on the ball.

(e) Explain why the distinction between speed and velocity is essential in this problem.