

**Massachusetts Institute of Technology
Department of Physics**

8.01X

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Practice Exam 3

Problem 1: A skydiver of $m = 8.0 \times 10^1$ kg reaches a terminal velocity of 5.0×10^1 m/s. Suppose the diver falls 1.6 km. Assume there is a drag force acting on the skydiver.

- a). How long does it take the skydiver to fall 1.6 km?
- b) How much work does the gravitational force do on the falling diver?
- c) How much work does the drag force do on the falling diver?
- d) What is the power corresponding to the work done by the drag force? What is the total energy generated by the drag force? Where does this energy go?

Problem 2: A ball of mass 0.1 kg hangs from a string of length 0.5 m. It is hit horizontally so that it starts from its lowest position with a speed of 7.0 m/s. It then continues to travel freely in a vertical circle with negligible loss of energy.

- a) Find the speed of the ball at the top of the circle.
- b) Find the tension in the string when the ball is at the top of the circle.

Problem 3: A person, abandoned on a small asteroid of mass $m_1 = 2.6 \times 10^{15}$ kg and radius $r = 5.0 \times 10^3$ m, has a spring that has a spring constant $k = 400$ N/m. The person has a small pen of mass $m_2 = 10$ g which can carry a message.

- a) How far must the person compress the spring in order for the pen to escape from the gravitational field of the asteroid? Ignore all rotational motion of the pen.
- b) A spacecraft is orbiting the asteroid once every two hours. What is the radius of the spacecraft's orbit?
- c) What is the speed of the spacecraft?
- d) If the pen were launched straight up, what is the speed of the pen at the orbit radius of the spacecraft?

Problem 4 : Suppose you want to jump up by first crouching down and then pushing off the ground. You initially lower your center of mass by 0.2 m. The average force exerted by the floor on you is three times your weight. What is your upward speed as you pass through your standing position just as you are leaving the floor?

Problem 5: A cup containing 0.25 kg of water at 22 °C is placed in a microwave oven. After 60 s the temperature of the water is found to be 50 °C.

- a) How much heat flowed to the water?
- b) What was the average power delivered to the water?

Problem 6: (*Momentum, kinetic energy, and collision*) Suppose a mass $m = 2.0$ kg moves in the +x-direction with a speed $v = 2.0$ m/s on a frictionless surface. The mass then explodes into two pieces with the first piece $m_1 = 0.5$ kg moving backwards with a speed of $v_1 = 1.0 \times 10^1$ m/s. The second piece with a mass of $m_2 = 1.5$ kg moves forward.

- c) What is the speed of m_2 ?
- d) How much kinetic energy is lost or gained in the explosion?

Problem 7: A mass m_1 is initially moving in the positive x-direction with a speed $v_{1,0}$ and collides elastically with a mass m_2 , which is initially moving in the opposite direction with an unknown speed $v_{2,0}$. After the collision m_1 moves with an speed $v_{1,f} = v_{1,0} / 2$, at an angle $\theta_{1,f} = 90^\circ$ with respect to the positive x-direction. After the collision, m_2 moves with an unknown speed $v_{2,f}$, at an angle $\theta_{2,f} = -45^\circ$ with respect to the positive x-direction.

- a) Find the speed $v_{2,f}$ in terms of $v_{1,0}$, m_1 , and m_2 .
- b) Find the speed $v_{2,0}$ in terms of $v_{1,0}$, m_1 , and m_2 .
- c) Find the mass ratio m_1 / m_2 .

Problem 8: The rubber bands in Expt VS have a spring constant k and are attached to a mass m_1 . The rubber bands are initially stretched spring a distance y from the equilibrium position.

- a) What is the period of oscillation for this system?
- b) What is the velocity of the mass when it reaches the equilibrium position?
- c) When the rubber bands are completely compressed, a second mass $m_2 = 2 m_1$ is attached to the first mass, completely inelastically. What is the new period of the system?
- d) Will the rubber band-mass now extend to the same distance y ? Assume mechanical energy is conserved.