MOTION IN 2 AND 3 DIMENSIONS

1. **Balloons:** A water balloon is thrown horizontally at a speed of v_0 from the roof of a building that is h above the ground. At the same instant the balloon is realized, a second balloon is thrown down at v_0 the same height.
   (a) Determine which balloon hits the ground first.
   (b) Determine how much sooner it hits the ground than the other balloon.
   (c) Which Balloon is moving with the fastest speed at impact?

2. **Airplane:** An airplane flying upwards at v_{up} and at angle θ relative to the horizontal releases a ball when is it is h above the ground. Neglect any effects due to air resistance and calculate:
   (a) The time of it takes the ball to hit the ground
   (b) The maximum height of the ball
   (c) The horizontal distance the ball travels from the release point to the ground

3. **Rocket**: Student-engineers decided to test a rocket they had built on a horizontal segment of highway. The rocket was launched at an angle of $\varphi = 45°$ with respect to the horizontal. At the time of the launch another student is driving their truck along this same highway in the same direction as the rocket but at another location away from the launch point. The rocket reaches a maximum height of h and lands in the back of this truck as it comes back to earth. The truck is traveling with a constant speed of v_T during the time of the rocket flight. Assume that back of the truck and launching point of the rocket are at the exactly same height. Neglect air resistance.
   (a) What distance from the launching point was the truck when the rocket landed in it?
   (b) Where was the truck, relative to the launch point of the rocket, when it was launched?
   (c) An observer in the back of the truck measures the velocity and acceleration of the rocket while in flight. In the reference frame of the truck, what is the velocity and acceleration of the rocket when it is at its highest point on its trajectory?

4. **Ride:** An amusement park ride is composed of a horizontal wheel of seats that can be raised or lowered during the ride. The seats are arrayed on a circle of radius R, and the wheel of seats makes one complete revolution in t_s seconds about a vertical axis passing through the center of the ride. At the start of the ride the wheel is raised to the top of the ride, a distance of H above the starting height off the ground and is set into rotation about the vertical axis. The wheel of seats is then lowered with a *constant vertical velocity* of v_{drop} while the wheel continues to rotate about the vertical axis of the ride. Answer the following in terms of the constants given.
   (a) What is the speed of a person sitting in one of the seats on the ride relative to an observer on the ground?
   (b) Find the magnitude and direction of the acceleration of this rider.
   (c) What is the angle between the rider's velocity vector and the horizontal during rider's descent?

5. **Two Cars**: Car A is traveling east at v toward an intersection. As car A crosses the intersection, car B starts from rest 40 m north of the intersection and moves south steadily gaining speed at 2.0 m/s^2. Six seconds after A crosses the intersection, find
   (a) the position of B relative to A,
   (b) the velocity of B relative to A, and
   (c) the acceleration of B relative to A.

6. **Cliff Jump**: Because of your knowledge of physics, you have been hired as a consultant for a new James Bond movie, "Oldfinger". In one scene, Bond jumps horizontally off the top of a cliff to escape a villain. To make the stunt more dramatic, the cliff has a horizontal ledge a distance h beneath the top of the cliff which extends a distance L from the vertical face of the cliff. The stunt coordinator wants you to determine the minimum horizontal speed, in terms of L and h, with which Bond must jump so that he misses the ledge.

7. **Catapult Problem**: Catapults date from thousands of years ago, and were used historically to launch everything from stones to horses. During a battle in what is now Bavaria, inventive artillerymen from the united German clans launched giant spaetzle from their catapults toward a Roman fortification whose walls were H high. The catapults launched spaetzle projectiles from a height of h above the ground, and a distance of L from the walls of the fortification at an angle of 60.0 degrees above the horizontal. The projectiles were to hit the top of the wall, splattering the Roman soldier atop the wall with pulverized pasta. (For the following questions, ignore any effects due to air resistance.)
   (a) What launch speed was necessary?
   (b) At what speed did the projectiles hit the wall?

8. **River Crossing**: You are a member of a geological team in Central Africa. Your team comes upon a wide river that is flowing east. You must determine the width of the river and the speed of the current (the speed of the water relative to the earth). You have a small boat with an outboard motor. By measuring the time it takes to cross a pond where the water isn't flowing, you have calibrated the throttle settings to the speed of the boat in still water. You set the throttle so that the speed of the boat relative to the river is a constant v_1. Traveling due north across the river, you reach the opposite bank in t_1. For the return trip, you change the throttle setting so that the speed of the boat relative to the water is v_2. You travel due south from one bank to the other and cross the river in t_2.
   (a) How wide is the river, and what is the speed of the current?
   (b) With the throttle set so that the speed of the boat relative to the water is 6.00 m/s, what is the shortest time in which you could cross the river, and where on the far bank would you land?

9. **Motorcycle Ride**: Starting from rest at point A, you ride your motorcycle north to point B 75.0 m away, increasing speed at a steady rate of 2.00 m/s^2. You then gradually turn toward the east along a circular path of radius 50.0 m at constant speed from B to point C, until your direction of motion is due east at C. You then continue eastward, slowing at a steady rate of 1.00 m/s^2 until you come to rest at point D.
   (a) What is your average velocity and average acceleration for the trip from A to D?
   (b) What is your displacement during your trip from A to C?
   (c) What distance did you travel for the entire trip from A to D?