Problem Set 10

Collisions

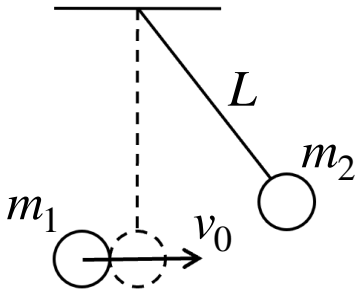
PHYS-101(en)

1. A collision

A ball of mass m_1 is traveling with a horizontal velocity v_0 and hits a second ball of mass m_2. This second ball is initially hanging on a vertical cord of length L. What is the maximum height attained by the second ball in the following cases:

1. The collision between the two balls is perfectly elastic
2. The collision between the two balls is inelastic and they stick together

Numerical application: $m_1 = 0.1$ kg, $m_2 = 0.2$ kg, $L = 30$ cm, $v_0 = 1$ m/s.



2. Bouncing balls

Two balls of mass m_1 and m_2 are released with no initial velocity from a height h as shown below. Ball 1 is directly beneath ball 2 and they are touching. During their fall, the balls stay in contact until they hit the ground. The situation can be described as an elastic collision between ball 1 and the ground, immediately followed by a collision between the two balls. Note that you can assume the radii of the balls are negligibly small, as is air drag. Answer all the questions below for both of the following cases:

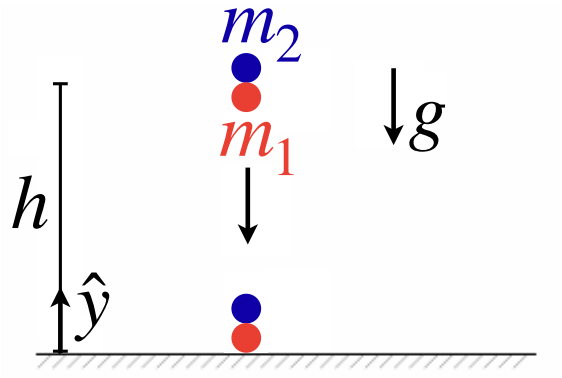
1. The collision between the two balls is perfectly elastic
2. The collision between the two balls is inelastic and they stick together

a) What are the velocities of each ball immediately after the second collision?

b) What is the condition between m_1 and m_2 for the balls to both attain an upwards velocity?

c) What is the condition between m_1 and m_2 for the first ball to stay on the ground?

d) What is the maximum height h_{2max} attained by the second ball if $m_1 \gg m_2$?



3. Damped cannon

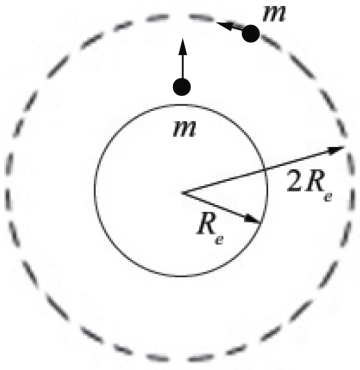
A cannon with a mass of $M = 10$ tons shoots a cannonball with mass $m = 10$ kg at an angle of $\alpha = 45°$. The cannonball lands a distance of $P = 40$ km away. The recoil of the cannon is absorbed by a spring with a stiffness of $k = 10^5$ N/m that is at its equilibrium position before the shot is fired. Neglect friction, air drag, and small variations in gravitational potential energy due to the cannon's motion.

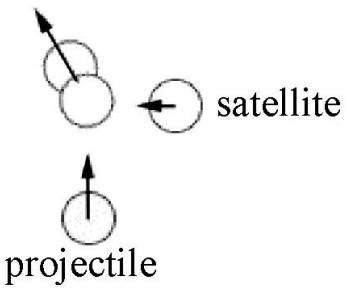
1. How far does the spring compress during the shot?
2. What was the energy delivered by the explosion of the powder in the cannon?

4. Space collision

A projectile of mass m is fired vertically from the earth's surface with an initial velocity that is equal to the *escape velocity*. The escape velocity is defined as the minimum velocity that is required for an object to escape the gravitational field of a celestial body (e.g. the earth). It satisfies the condition that the total mechanical energy (i.e. kinetic plus gravitational potential) is equal to zero. When the projectile is a distance $2R_e$ from the center of the earth, it collides with a satellite of mass m that is orbiting the earth in a circle. After the collision the two objects stick together. Assume that the collision is instantaneous, neglect atmospheric drag, and let the reference point for the gravitational potential be at infinite distance.

Express your answers to the questions below in terms of m, the radius of the earth R_e, the mass of the earth M_e, and the universal gravitational constant G.





1. What is the initial speed of the projectile when it is launched from the surface of the earth?
2. What is the speed of the projectile just before the collision, when it is a distance $2R_e$ from the center of the earth?
3. What is the speed of the satellite just before the collision, when it is in a circular orbit of radius $2R_e$?
4. What is the speed of projectile and satellite immediately after the collision?

5. Stream bouncing off a wall

A stream of particles hits a flat surface and rebounds along the original line of motion with the same speed. Every particle has the same mass m and speed v and the particles are regularly spaced with a separation distance d. What is the magnitude of the average force experienced by the surface?