



(Figure 3). If  $M$  is stationary, find (a) the tension in the string and (b) the period of circular motion.

9. A 1000-kg car is on a country road which has its ups and downs or maxima and minima in height. Right now it is at the top of a bump (a maximum) that has a radius of curvature of 20 m. What is the maximum speed at which the car can maintain road contact at the bump? If next it is at the bottom of a dip (a minimum) of the same radius, moving at the same speed, what force does the ground exert on the car?
10. The handle of a 22-kg lawnmower makes a  $35^\circ$  angle with the horizontal. If the coefficient of friction between lawnmower and ground is 0.68, what magnitude of force is required to push the mower at constant velocity? Assume the force is applied in the direction of the handle. Compare with the mower's weight.
11. A roller coaster of mass  $M$  is at the top of the Loop-the-loop of radius  $R$  at twice the minimum speed possible. What force does the track exert on it? What force does it exert when it is at the bottom of the circle? (Use conservation of energy if needed.)
12. Consider Figure (4) with  $\mu_s$  the coefficient of static friction between  $M$  and the plane. Let masses initially be at rest. Imagine mass  $m$  is varied continuously to cause motion. Find the range of values of  $m$  for which (i)  $M$  will begin to slide down hill as  $m$  is reduced (ii) when  $M$  will begin to go uphill as  $m$  is increased. What happens in between these values? Argue that motion up or down is possible for  $m$  even in this range if we give the masses a little push. What is the range of  $m$  when such motion is possible? Why is it that if we increase  $m$  enough it will necessarily drag  $M$  up hill, but an  $M$ , no matter how large may not be able to cause  $m$  to go up?
13. I pull a mass  $m$  resting at  $x = 0$  on a frictionless table connected to a spring with some  $k$  by an amount  $A$  and let it go. (i) What will be its speed at  $x = 0$ ? (ii) How far to the left will it go and why? (ii) Repeat (i) when the coefficient of friction with table is  $\mu_k$  (iv) Repeat (II) with friction.

FIG. 1. Two strings making angles  $a$  and  $b$  meet at a point and support a mass  $10\text{ kg}$ .

FIG. 2. Spring has force constant  $k$ . The coefficient of friction between masses is  $\mu$  in both parts and is  $\mu^0$  between lower mass and table in part (ii)

FIG. 3. The mass  $m$  is going around in a circle of radius  $R$  on a table. It is connected by a massless rope to  $M$ , hanging under the table.

FIG. 4. The coefficient of static (kinetic) friction between  $M$  and plane is  $\mu_s$  ( $\mu_k$ ).