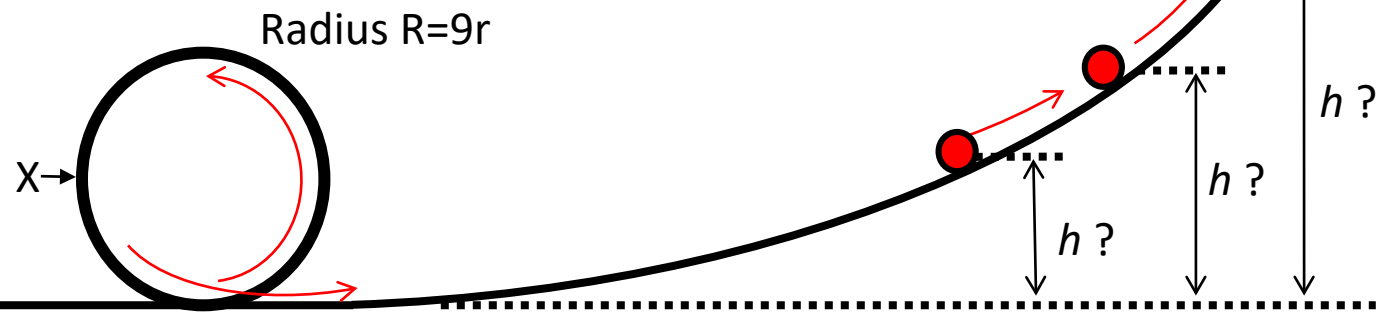
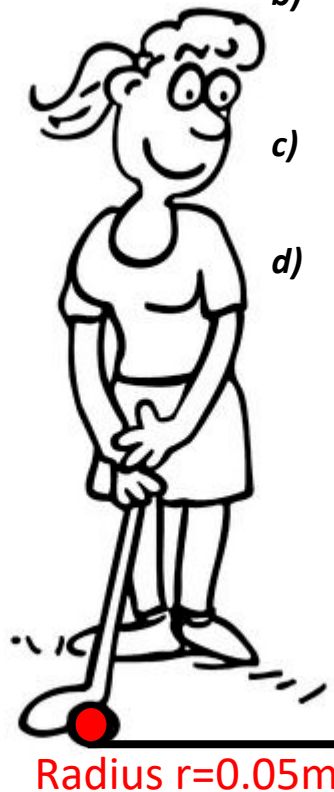


**60 minutes exam (open book): 8am-9am California time. Submit your work as one pdf before 9:10am.**  
**You are not allowed to communicate with other students or consult the internet.**

**1) Golf ball on a track with a loop (10 points).**

A solid golf ball of mass  $m=0.1\text{ kg}$  and radius  $r=0.05\text{m}$  is hit by a golf stick so that it will roll without slipping by the time it reaches the loop of radius  $R=16r$  in the track. The ball keeps rolling without slipping. On entering the loop the ball has a center of mass velocity  $v$ .

- a) (3 points)** What should be the minimum velocity  $v_{top}$  (at the top of the loop) so that the ball will go all the way around the loop? (Hint: you might want to quickly review Chapter 3.4 of the book).
- b) (3 points)** What is the minimum velocity  $v_{bottom}$  (at the bottom when entering the loop) so that the ball will have  $v_{top}$  at the top of the loop? (you can still answer this question if you did not do part a) by assuming the ball has velocity  $v_{top}$  at the top of the loop)?
- c) (2 points)** With this minimum velocity  $v_{bottom}$  (on entering the loop), how hard will the track push on the ball at point X?
- d) (2 points)** After leaving the loop the ball rolls up a hill (without slipping). How high up the hill will the ball roll? (you can still answer this question if you did not do part a)-c) by assuming the ball has velocity  $v$  when exiting the loop)



## 2) Transporting a refrigerator (10 points)

Two movers carry a refrigerator by placing it on a light board 3.00 m long. The refrigerator is a cube of 1 cubic meter with its center of mass at the center of the cube. One person lifts at one end of the board with a force of 369 N, and the other lifts the opposite end with a force of 711 N.

- (a) (3 points)** What is the weight of the refrigerator, and where along the board is its center of gravity located?
- (b) (3 points)** Suppose the board is not light but weighs 234 N, with its center of gravity at its center, and the two people each exert the same forces as before. What is the weight of the refrigerator in this case, and where is its center of gravity located?
- (c) (4 points)** Now the movers have to go up the stairs (using the values from part (b)). The stairs make an angle of 30 degrees with the floor. The refrigerator is securely tight to the board so that it will not slip. The person who lifted with a force of 711N goes in front and will only apply a force perpendicular to the stairs. Make a free-body diagram and calculate the forces which the two movers have to exert while standing still on the stairs?