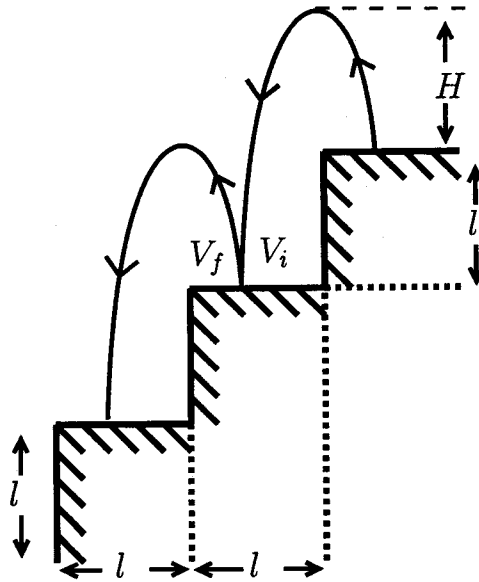


# QP44

## Playing Marbles



A marble bounces down a long flight of stairs in a regular manner, hitting each step vertically at the same speed and distance from the edge, and bouncing up to the same height above each step, as shown in the figure below. Each stair has the same height and depth  $l$ , as shown. The *horizontal* component of velocity  $V_h$  is unaffected, but the stairs have the property that  $-V_f/V_i = e$ , where  $V_i$  and  $V_f$  are the *vertical* velocity components just before and after the bounce respectively, and  $e$  is a constant ( $0 < e < 1$ ).

Ignore the size of the marble and air resistance in answering the following questions. Assume the trajectory of the marble lies in plane of the paper.

- [2 points] Find an expression for  $V_i$  in terms of  $e$ ,  $l$ , and the acceleration of gravity  $g$ .
- [2 points] Find the time between bounces in terms of  $e$ ,  $l$ , and  $g$ .
- [1 point] Find an expression for the bouncing height,  $H$ , in terms of  $l$  and  $e$ .