

## STEP II, 2012 Q11

- 11 A small block of mass  $km$  is initially at rest on a smooth horizontal surface. Particles  $P_1, P_2, P_3, \dots$  are fired, in order, along the surface from a fixed point towards the block. The mass of the  $i$ th particle is  $im$  ( $i = 1, 2, \dots$ ) and the speed at which it is fired is  $u/i$ . Each particle that collides with the block is embedded in it. Show that, if the  $n$ th particle collides with the block, the speed of the block after the collision is

$$\frac{2nu}{2k + n(n+1)}.$$

In the case  $2k = N(N+1)$ , where  $N$  is a positive integer, determine the number of collisions that occur. Show that the total kinetic energy lost in all the collisions is

$$\frac{1}{2}mu^2 \left( \sum_{n=2}^{N+1} \frac{1}{n} \right).$$



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