

## STEP II, 2004, Q10 MS

*Q10* If the retardation of the particles when moving up the plane is  $a_1 \text{ ms}^{-2}$ , then  $4g(\sqrt{3}/2)(1/5\sqrt{3}) + 2g = 4a_1 \Rightarrow a_1 = 6$ , so that  $P$  comes to rest after 1 second at  $D$  where  $AD = 3 \text{ m}$ .

If the acceleration of  $P$  down the slope is  $a_2 \text{ ms}^{-2}$ , then  $-4g(\sqrt{3}/2)(1/5\sqrt{3}) + 2g = 4a_2 \Rightarrow a_2 = 4$ .

Hence if  $P$  and  $Q$  meet at time  $\tau$ , then  $3 - 2(\tau - 1)^2 = 6(\tau - T) - 3(\tau - T)^2$

$\Rightarrow \dots \Rightarrow \tau^2 - (2 + 6T)\tau + 3T^2 + 6T + 1 = 0 \Rightarrow \dots \Rightarrow \tau = 1 + (3 - \sqrt{6})T$ .

Note that the condition  $T < 1 + \sqrt{3/2}$  ensures that the collision takes place before  $P$  returns to  $A$ .

(ii) A possible solution is first to show that  $T = 1 + \sqrt{2/3} \Rightarrow \tau = 2$ .

Hence as  $v_P(2) = 4 \text{ ms}^{-2}$ ,  $v_Q(2) = 2\sqrt{6} \text{ ms}^{-2}$  then the total KE at  $t = 2$  of  $P$  and  $Q = 80 \text{ j}$ .

Further, gain in PE at  $t = 2$  since start of motion =  $40 \text{ j}$  so that energy lost due to friction =  $144 - 80 - 40 = 24 \text{ j}$ .

Alternatively, and more directly, the work done against friction up to the moment of collision = frictional force opposing motion of  $P$  (or  $Q$ )  $\times 6 \text{ j} = 4 \times 6 = 24 \text{ j}$ .



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