Theoretical Question 2: Creaking Door

MARKING SCHEME

a1) 0.6	Understood in T_0, A calculation that the motion is purely harmonic	0.1	
	Result for T_0	0.2	
	Result for A	0.3	Correct amplitude $u - v_0$ of $\dot{x}$ – 0.1 Deducing A (using either direct division by ω or energy conservation in the moving frame) – 0.2
a2) 0.4	Sinusoidal shape with enough periods	0.1	
	Starts at a positive slope	0.1	
	Starts at $x > 0$	0.1	
	Positive mean value of x	0.1	Judge sparingly, penalize only in obvious cases
b) 1.2	Enough periods	0.1	
	Starts at $v = 0$ (stick)	0.1	
	Has finite segments with $v = 0$ (stick phases)	0.3	
	The "humps" (slip phases) are always above the horizontal segments	0.2	Always to the same side – 0.1 Always above – 0.1
	Continuity of $v$between the different segments	0.1	
	Slope (acceleration) discontinuity between the horizontal segments (stick) and the humps (slip)	0.1	
	u is drawn below the maximum of $v(t)$	0.3	
	Penalty for clearly unreasonable shape of the humps (very asymmetric, contain straight lines etc.)	-0.3	
c) 0.5	Correct result	0.5	Wrote the formal integral for $\langle x \rangle$ - 0.1
d) 2.4	Writing $T = t_{stick} + t_{slip}$	0.1	
	Finding the detachment offset $x_1 = (\mu_s - \mu_k)mg/k$ (or finding $2x_1$)	0.3	
	Finding the stick time $t_{stick} = 2x_1/u$	0.2	Correct except for factor-of-2 – 0.1
	Understanding that t_{slip} is part of a harmonic period T_0	0.2	
	Finding the phase corresponding to t_{slip}	1.1	Partial credit for the amplitude of the harmonic motion – 0.3
	Final result for t_{slip}	0.2	Correct except for factor-of-2 – 0.1
	Final result for T	0.3	Correct except for factors-of-2 – 0.2 Otherwise, no credit for propagating errors.
e) 2.4	Understanding that at u_c, the box sticks back to the floor at the equilibrium of the harmonic motion	0.4	
	Understanding that at u_c, $t_{stick} \ll t_{slip}$	0.4	

	Writing correct equations for u_c	1.2	Partial credit for correct equations involving the amplitude A of the harmonic motion or the detachment phase φ, without finding them – 0.4
	Final answer	0.4	
f) 1.0	Relation between τ and α	0.4	
	Relation between α and θ	0.4	
	Final answer	0.2	Any expression which reduces to the official one in the limit $\Delta r \ll r$ will be accepted.
g) 1.5	Understanding that $t_{stick} \gg t_{slip}$	0.2	
	Correct expression for the result	1.0	Any expression which reduces to the official one in the limit $\Delta r \ll r$ will be accepted. Penalty for factor-of-2 (when not propagated) – 0.2 Partial credit for using t_{stick} from part (d) without taking the limit $t_{stick} \gg t_{slip}$ - 0.3
	Correct numerical result	0.3	A numerical result without an expression will not receive credit. If the expression was acceptable but is different from the official one, the result will be graded according to the student's expression.