Theory
Q1
RF reflectometry for spin readout for silicon quantum computing
Marking scheme. Version 1.1

Question part	Total marks	Partial marks	Explanation for partial marks and special cases
A.1	0.2	0.1	Velocity dimensionally correct and is less than c
		0.1	Correct final answer
			• 0.2 total for correct answer with no justification
A.2	0.2	0.1	Applying Gauss theorem
		0.1	Correct final answer
	0.3	0.1	Capacitance formula
		0.1	Electric potential formula
		0.1	Correct final answer
A.4	0.3	0.1	Bio-Savart law or equivalent for magnetic field of a wire
		0.1	Inductance formula
		0.1	Correct final answer
A.5-i	0.8	0.1	Adding one extra δL, δC link does not change the semi-infinite wire
		0.1	Equating impedance the circuit with one extra link to Z_0
		0.1	Sum of impedance in parallel (L and Z_0)
		0.1	Sum of impedance in series
		0.1	Correct equation for Z_0
		0.1	Relating δL, δC to L_x, C_x
		0.1	$\delta L \rightarrow 0$ limit simiplification
		0.1	Correct final answer
A.5-ii	0.2	0.1	Correct b/a formula
		0.1	Correct final answer
B.1	1	0.1	Z_0 in terms of L_x, C_x
		0.2	Method of images
		0.1	Magnetic flux and its relation to L_x
		0.1	Adding B-fields of the real and the imaginary wires
		0.1	Correct L_x
		0.1	Potential and its relation to C_x
		0.1	Adding E fields of two wires
		0.1	Capacitance per length C_x
		0.1	Final result for Z_0
C.1	1	0.1	Starting with a workable approach (would lead to answer if followed through)
		0.1	Concept of equating voltage amplitudes
		0.1	Correct voltage matching equation
		0.1	Current conservation concept
		0.2	Current conservation equation (-0.1 if signs are wrong)
		0.1	Apply Omh's law
		0.1	Correct equation to solve for V_r/V_i
		0.1	Solving the equation
		0.1	Final answer in term of Γ
			• Proof of work required. Max 0.2 for stating the answer with no proof
C.2	0.2	0.1	π-shift of reflected signal implies $\Gamma < 0$
		0.1	Correct condition stated

D.1(i)	1		A variety of approaches acceptable if lead to correct answer
		0.1	Charge on QD equals $-ne$
		0.3	Treat charge on the QD as the charge on C_g(neglecting tunnel junctions)
		0.3	Voltage drop across capacitor computed correctly
		0.3	Equation for φ_n in terms of sum of voltages(-0.1 if signs are wrong)
			• -0.1 if the term with ½ is missing
D.1(ii)	0.5		A variety of approaches acceptable if lead to correct answer
		0.1	Relation between energy and potential
		0.3	Correct intermediate formula for ΔE_n
		0.1	Correct final answer
D.2	0.5	0.2	A difference of ΔE_n and ΔE_{n+1} considered
		0.1	Use the formula from D.1(ii) for ΔE_n.
		0.2	Correct final answer
D.3	0.5	0.2	$k_B T$identified the relevant thermal energy
		0.2	E_c identified as the relevant scale for electron energy
		0.1	Correct final answer
			• no penalty for numerical prefactors of order 1 or using $\ll$ instead of $<$
D.4	0.8	0.2	$\tau \sim R_t C_t$ tau on order of RC
		0.3	h/τ is identified as relevant scale for the fluctuation energy
		0.1	E_c identified as the relevant scale for electron energy
		0.2	Correct comparison sign and correct final answer
			• answer for τ without justification acceptable
			• no penalty for numerical prefactors of order 1 or using $\ll$ instead of $<$
E.1	0.2	0.1	At least one of Γ computed correctly
		0.1	Correct final answer
E.2	0.8	0.1	Understand $\Delta\Gamma \sim 1$ requires change in Z_{tot} on the order of Z_0
		0.1	Identifying OFF state as an LC circuit
		0.2	Choosing L_0 from the LC resonance condition
		0.1	Calculate Γ_{OFF}
		0.1	Correct Z_{tot} for ON state
		0.1	Correct numerical answer for L_0
		0.1	Correct numerical answer for Γ_{ON}
F.1	1	0.1	Calculate Z_{tot} for OFF state
		0.2	Choosing $\omega_{rf}$to match a resonance
		0.2	Calculate Z_{tot} for ON state
		0.3	Connect $\Delta\Gamma \sim 1$ with Z_{tot} values
		0.2	Correct calculation and final answer
F.2	0.5	0.1	Diagram with the added element is functional
		0.2	Capacitance in series with the rest of the circuit
		0.1	Demonstrate that the added element leads to $\Delta\Gamma \sim 1$
		0.1	Correct formula characterizing the added element