Theoretical Question 1: The Shockley-James Paradox

MARKING SCHEME

a) 1.0	Finding B at the center	0.3	
	Writing $\Phi_{B1} = \pi r^2 B$	0.3	
	Final answer	0.4	No credit for internal propagating error
b) 0.8	Understanding that $\Phi_{B2} = MI_1$	0.2	
	Understanding that $\varepsilon_2 = -\dot{\Phi}_{B2}$	0.2	Disregard sign
	Final answer	0.4	No credit for internal propagating error
c) 0.5	Writing $\varepsilon_2 = 2\pi r E$	0.3	Partial credit for $\varepsilon_2 = \oint E dl$ - 0.1
	Final answer	0.2	No credit for internal propagating error
d) 1.0	Writing $F = QE$	0.2	
	Writing F as a function of $\dot{I}_1$	0.2	
	Writing $\Delta p = \int F dt$	0.2	
	Final answer	0.4	
e) 1.1	Understanding that $N = nlA$	0.2	
	Understanding that $v = I/(nAq)$	0.3	
	Understanding that $p = Nmv/\sqrt{1 - v^2/c^2}$ (or γNmv)	0.3	
	Final answer	0.3	No credit for internal propagating error
f) 3.3	Understanding that $I = \lambda qv$ or $I = nAqv$	0.3	
	Understanding that there are separate $v_{1,2}$ and $\lambda_{1,2}$ (or $n_{1,2}$)	0.4	
	Expressing p_{hid} in terms of the charge densities and velocities	0.4	E.g. $p_{hid} = ml(\lambda_2\gamma_2 v_2 - \lambda_1\gamma_1 v_1)$
	Cancelling out the charge densities	0.7	E.g. $p_{hid} = (\gamma_2 - \gamma_1)Ilm/q$
	Understanding that $\Delta E_k = \Delta U$	0.5	
	Finding $\Delta U = kQql/R^2$	0.4	
	Final answer	0.6	If the result was reverse-engineered from part (g), this will be the only credit given. No credit for internal propagating error.
g) 0.8	Writing $\mu = I\pi r^2$ for part (d)	0.1	
	Re-expressing the result of part (d)	0.3	
	Writing $\mu = Il^2$ for part (f)	0.1	
	Re-expressing the result of part (f)	0.3	No credit here if the answer to (f) was reverse-engineered.
h) 1.5	Correct answer (yes/no) for each statement	0.5*3	No credit at all if a statement was decided incorrectly.