Experimental Question 1: Levitation of Conductors in an Oscillating Magnetic Field

MARKING SCHEME

a) 0.2	Correct expression for ϵ	0.1	Disregard overall sign
	Correct expression for I	0.1	Disregard overall sign
b) 0.6	Understanding Gauss law for cylinder: $\Delta\Phi_z = \Phi_r$	0.3	
	Writing $\Phi_r = 2\pi r \Delta z B_r$	0.1	
	Result for B_r	0.2	Disregard overall sign
c) 0.5	Writing $F(t)$ correctly	0.1	
	Decomposing into sine-squared and sine-cosine products	0.2	
	Final answer	0.2	
d) 1.3	Reasonable circuit diagram for measuring current and voltage	0.1	
	Correct 4-terminal circuit diagram	0.2	
	Current and voltage measurements	0.3	At least 3 measurement sets – 0.3 2 measurement sets – 0.2 1 measurement set – 0.1
	Took into account that the measured voltage is not on the whole ring	0.1	
	Result for the resistance	0.5	Within 1.67mΩ-1.74mΩ - 0.5 Within 1.62mΩ-1.79mΩ - 0.3 Within 1.35mΩ-2.05mΩ - 0.1
	Error estimation	0.1	
e) 1.3	Measurement of closed ring's average diameter	0.2	
	Weighing the rings	0.1	
	Writing $R_2/R_1 = (l_2/l_1)(A_1/A_2)$	0.1	
	Writing $A_1/A_2 = (l_2/l_1)(m_1/m_2)$	0.2	
	Taking into account the gap in the open ring	0.1	
	Result	0.4	Within 0.150mΩ-0.160mΩ - 0.4 Within 0.145mΩ-0.165mΩ - 0.2 Within 0.120mΩ-0.190mΩ - 0.1
	Error estimation	0.2	
f) 1.5	Range of measured EMF	0.3	At least 5mV-20mV – 0.3 At least 7mV-14mV – 0.1
	Number of measurement points	0.3	At least 30 points – 0.3 20-29 points – 0.1
	Calculating z from number of turns	0.2	Either for each separate point or as a collective statement of units
	Penalty for not writing correct units in the table	-0.1	

	Graph of $\epsilon(z)$	0.7	Reasonably smooth shape – 0.2 Using most of the paper area – 0.2 Error bars – 0.1 Axes properly marked – 0.1 Units – 0.1
g) 1.0	Range of measured force	0.3	At least 0.3gf-5.5gf – 0.3 At least 0.6gf-3gf – 0.1
	Number of measurement points	0.3	At least 30 points – 0.3 20-29 points – 0.1
	Calculating z from number of turns	0.2	Either for each separate point or as a collective statement of units
	Subtracting the weight of the ring+block	0.1	Either with Tare option or manually
	Errors	0.1	
	Penalty for not writing correct units	-0.1	
h) 1.4	Finding the derivative $d\epsilon/dz$ or $d\epsilon^2/dz$ using differences between points on a smoothed graph	1.1	Drawing a smooth line on the graph (not exactly along the points) – 0.2 Finding the derivative from differences between points on the smooth line – 0.5 Using symmetric pairs of points for the derivative calculation – 0.2 Using reasonable spacing of the pairs of points – 0.2
	Finding the derivative of $d\epsilon/dz$ or $d\epsilon^2/dz$ using differences between measured points		Finding the derivative from differences between the measured points – 0.4 Using symmetric pairs of points for the derivative calculation – 0.2 Using reasonable spacing of the pairs of points (6mm-12mm) – 0.5 (Partial credit for spacing of 4mm-6mm or 12-15mm – 0.2)
	Finding the derivative by drawing tangents to the graph		Partial credit of 0.3 out of 1.1 for using this method.
	Number of points where the derivative was found	0.3	At least 15 points – 0.3 10-14 points – 0.1
i) 2.2	Graph	0.7	Appropriate axes (e.g. $\langle F\rangle$ vs. $d\epsilon_{rms}^2/dt$), properly marked – 0.2 Using most of the paper area – 0.2 Error bars – 0.2 Units – 0.1
	Using a linear region for the slope	0.2	
	Finding the slope	0.1	
	Error of the slope	0.1	

	Expressing L from the slope	0.2	Writing an equation for L – 0.1 Solving the equation (with correct root) – 0.1 Partial credit for neglecting $\omega L/R$ and a correct calculation otherwise – 0.1
	Result for L	0.7	0.110μH-0.121μH - 0.7 0.100μH-0.130μH - 0.4 0.090μH-0.140μH - 0.1
	Error calculation for L	0.2	