E1. Static response of a magnetically active fluid
Marking scheme. Version 1.5a

Question part	Total marks	Partial marks	Explanation for partial marks and special cases
A.1	0.8	0.1 0.5 (0.2) 0.2	Diagram of a useful setup Full marks for z within range (0.070 ± 0.003)m For z within range (0.07 ± 0.01)m Uncertainty estimate (reasonable, <= 35%); if 2mm 0.1
A.2	0.8	0.3 (-0.1) (-0.1) 0.3 0.2	Correct formula $\Delta\rho g = 3\chi B_r^2 a^4 l^2/(8\mu_0 z^7)$ If measured a or l incorrectly instead of using given value (if good measurement of a or l, give full points) If $\Delta\rho$ out by ~10 but dimensionally correct No marks if dimensionally incorrect (eg. no g) Value of $\Delta\rho$=4.1 kg· m^{-3} (e.c.f. full marks for wrong z in A.1 – see figure) Uncertainty estimate (1.2 kg· m^{-3})
B.1	0.6	0.2 0.1 0.2 0.1	Value for $z_{crit} = 41 \pm 1$mm (or 22 ± 1mm full points using small magnet) Uncertainty for z_{crit} at most 2mm Value for $\lambda = 10 \pm 1$ mm Uncertainty for λ at most 2mm
B.2	0.6	0.3 0.2 0.1	Value for $\sigma = 1.0 \cdot 10^{-4}\ N \cdot m^{-1}$, correct with an order of magnitude (e.c.f. -0.1 for wrong Δ) Uncertainty estimate $\frac{\Delta\sigma}{\sigma} = \frac{7\Delta z}{z} + \frac{2\Delta\lambda}{\lambda}$ Relative uncertainty less than 70%
C.1	0.6	0.2 0.2 0.1 0.1	Diagram of a useful setup – needs to show clearly the measured quantity and the setup Measurements (at least 3) and calculations (0.1 for 1 measurement giving good value of for Δz) Value for $\Delta z = 0.80 \pm 0.02$ mm Uncertainty estimate <3%
C.2	3.5	1.0 0.5 0.3 0.7 0.5 0.5	Raw measurements for # of turns and M (1.0 for 18+ data points, 0.2 per 4 data points if <18, no points for changing l) Correct conversion to R Graph shows both regions Graph has 18+ correct data points (or if not 18+, 0.2 per 6 data points, plotted correctly) Good fit to correct region Answer n with range 6 -- 7 with uncertainty
D.1	0.5	0.5	Value for $\sigma = 1.1 \cdot 10^{-2} N\ m^{-1}$ • Full mark if within 30%, 0.2 – within 50%, else – 0
D.2	1.0	0.9 (0.6) (0.4) 0.1	5+ up, 6+ down 5+ up, 5+ down 4+ up, 4+ down No points if only in one direction Reasonable uncertainty estimate
D.3	1.0	0.3 (-0.1) (-0.1)	Correctly plotted graph No error bars if uncertainty in D2 large enough to plot Only one direction

		0.2 0.2 0.3	One smooth curve fitting points Second smooth curve fitting points Clear hysteresis shown: at least 1.5 mm separation in z (0.1 if separated by less, 0 if lines cross)
D.4	0.6	0.2 0.2 0.2	Correct graph for surface energy Correct graph for magnetic energy Correct step behavior for both graphs