Grading Scheme for Experimental Problem – 2

No fraction less than 0.1 marks should be given for any answer. Nowhere marks are to be deducted according to the marking scheme.

Part 1

Quantity observed	Magnitude to be checked	criteria	marks	Total
Part 1				
a)Coil 1 air core				
Measured voltages	$\|V - V_{R'}\|$ (R′ ≈ 450 Ω)	≤ 0.15 V	0.1	
Measured voltages	V_A, V, $V_{R'}$,Vo	Measured once	0.1	
	V_A, V, $V_{R'}$,Vo	Measured second time reversing the DMM polarity	0.1	
Calculated value of Z_1		Between 435-465 Ω	0.1	
Calculated value of R_1		Between 40-47 Ω	0.1	
Calculated value of L_1		Between 0.069 - 0.073 H	0.1	
Standard uncertainty $u_S(R_1)$		Between 1.1 and 1.2	0.1	
Expanded uncertainty in R_1		± 3 Ω	0.1	
Expanded uncertainty in L_1		± 0.0002 H	0.1	
				0.9
b)Coil 2 air core				
Measured voltages	$\|V - V_{R'}\|$ (R′ ≈ 350 -360 Ω)	≤ 0.15 V	0.1	
	V_A, V, $V_{R'}$,Vo	Measured once	0.1	
	V_A, V, $V_{R'}$,Vo	Measured second time reversing the DMM polarity	0.1	
Calculated value of Z_2		Between 335-365 Ω	0.1	
Calculated value of R_2		Between 40 – 47 Ω	0.1	
Calculated value of L_2		Between 0.052 - 0.059 H	0.1	
Standard uncertainty $u_S(R2)$		Between 0.85 and 0.97	0.1	
Expanded uncertainty in R_2		± 3 Ω	0.1	
Expanded uncertainty in L_2		± 0.0001 H or ± 0.0002 H	0.1	
				0.9
c) Coil 1 Al core				
Measured voltages	$\|V - V_{R'}\|$ (R′ ≈ 300 Ω)	≤ 0.15 V	0.1	

	V_A, V, $V_{R'}$,Vo	Measured once		
	V_A, V, $V_{R'}$,Vo	Measured second time reversing the DMM polarity	0.1	
Calculated value of Z_1*		Between 280-310Ω	0.1	
Calculated value of R_1*		Between 100 – 110 Ω	0.1	
Calculated value of L_1*		Between 0.042 - 0.046 H	0.1	
Standard uncertainty $u_S(R^*_1)$		Between 1.1 and 1.4	0.1	
Expanded uncertainty in R_1*		± 3 Ω	0.1	
Expanded uncertainty in L_1*		± 0.0002 H	0.1	
				0.8

d) Coil 2 Al core				
Measured voltages	|V- $V_{R'}$ | (R´ ≈ 280 Ω)	≤ 0.15 V	0.1	
	V_A, V, $V_{R'}$,Vo	Measured once		
	V_A, V, $V_{R'}$,Vo	Measured second time reversing the DMM polarity	0.1	
Calculated value of Z_2*		Between 275 – 285 Ω	0.1	
Calculated value of R_2*		Between 64-76 Ω	0.1	
Calculated value of L_2*		Between 0.040 - 0.044 H	0.1	
Standard uncertainty $u_S(R^*_2)$		Between 0.91 and 1.2	0.1	
Expanded uncertainty in R_2*		± 2 Ω or ± 3 Ω	0.1	
Expanded uncertainty in L_2*		± 0.0002 H	0.1	
				0.8

Part 2				
f) M & k				
Calculated value of M_{air}	ωM = R´ (Vo/ $V_{R'}$) mean of both coils	0.052H (range of ± 0.002 H)	0.1	
k_{air}		0.84 (range of ± 0.02)	0.1	
Calculated value of M_{Al} or M*	ωM* = R´ (Vo/ $V_{R'}$) mean of both coils	0.034 H (range of ± 0.001 H)	0.1	
k_{Al} or k*	Observed k*= k - 0.04	(allow ±0.02)	0.1	
				0.4
g) Measured voltages	R_L and V_A, V, $V_{R'}$,Vo			
	no of readings :	5	0.4	
	no of readings :	6 **add**	0.1	

	no of readings :	7 **add**	0.1	
	Choice of R_L and choice of step; Effect of R_L will be noticed when its magnitude is of the order of X_S.	with equal steps 100,200,300 Ω etc to cover range up to 700 to1000 Ω	0.1	
	Two readings for each voltage	with reversal for correction of asymmetry	0.1	
				0.8
h) Linearised relation	$(\omega M)^2(Ip/Is)^2 = (Rs + R_L)^2 + Xs^2$ Or $(Rs + R_L)^2 = (\omega M)^2(Ip/Is)^2 - Xs^2$	Correct rearrangement	0.2	
				0.2
i)	Number of secondary data generated from data of (g)	4	0.2	
		5 **add**	0.2	
		6 **add**	0.2	
Calculated values	$Ip = V_{R'} /300$	Correct calculation	0.1	
Calculated values	$Is = Vo/R_L$	Correct calculation	0.1	
Calculated values	$(Rs + R_L)^2$	Choice of correct value of Rs (= R_2 of coil 2: air core)	0.1	
				0.9
j) Graph of $(Rs + R_L)^2$ vs $(Ip/Is)^2$	Proper choice of scale to occupy graph space (about 70% or more)		0.1	
	Proper choice of origin To get intercept		0.1	
	M from slope	Between 0.050-0.54 H	0.1	
		If between 0.051-0.52 H **add**	0.1	
	Xs from intercept	Between 320-385 Ω	0.1	
		If between 335-360 Ω **add**	0.1	
	More than 5 points on straight line		0.1	
				0.7
Part 3				
k) Calculations of R_{PE} and X_{PE}				
	$R_{PE} = (300/2)[(V_A{}^2 - V_P{}^2)/ V_{R'}{}^2 - 1]$	Correct formula used	0.1	
	Number of data points calculated	5	0.1	
	Number of data points calculated	6 **add**	0.1	
	$X_{PE} = [Z_{PE}{}^2 - R_{PE}{}^2]^{1/2}$	Correct formula used	0.1	
	Number of data points calculated	5	0.1	
	Number of data points calculated	6 **add**	0.1	

				0.6
l) Calculations of R_R and X_R				
	R_R = $(Rs + R_L)/(Ip/Is)^2$	Correct formula used	0.1	
	Number of data points calculated	5	0.1	
	Number of data points calculated	6 **add**	0.1	
	X_R = $Xs/(Ip/Is)^2$	Correct formula used	0.1	
	Number of data points calculated	5	0.1	
	Number of data points calculated	6 **add**	0.1	
				0.6
m) Graph of X_{PE} vs X_R				
	Right choice of scale (to occupy more than 70% space)		0.1	
	Right choice of origin to get intercept		0.1	
	slope	Between - 0.9 &-1.1	0.1	
	Intercept	Xp (found from part 1) ± 20 Ω	0.1	
	More than 5 points on the st.line		0.1	
	Inference $Xp - X_R = X_{PE}$		0.1	
				0.6
n) Graph of R_R vs R_L				
	Choice of scale (to occupy more than 70% space)		0.1	
	Smooth curve		0.1	
	Peak shown is unambiguous		0.1	
	R_R is maximum at $R_L = Xs - Rs$	R_L should be X2 – R2 in a range of ± 20 Ω	0.1	
		If the range is ± 5 **add**	0.2	
				0.6

Part 4				
o) Model for Al core				
	$L_{core}/R_{core} = (Xp - X^*)/(R^* - Rp)2\pi f$	Correct formula showing clear understanding of concepts	0.4	
	Calculated value for coil 1	Lc/Rc ≈ 0.0046 H/Ω (a range of±0.003 H/Ω)	0.2	
	Calculated value for coil 2	Lc/Rc ≈ 0.0046 H/Ω (range of ±0.003 H/Ω)	0.2	
				0.8
p) Power loss in core				
measurements	V_A, V, $V_{R'}$,Vo with R´ =300 Ω and R_L = 1000 Ω			

	same	With reversal of polarity	0.1	
	$\Delta P = Ip^2(R_{PE} - Rp) - Is^2(R_S + R_L)$	Correct concept	0.2	
	Calculated value	ΔP = 0.016 W (± 0.001 W)	0.1	
				0.4
				10.0

Note on uncertainty in R1, L1 etc.:

The combined standard uncertainty $u_c = \sqrt{(u_{sy}^2 + u_{res}^2)}$. Expanded uncertainty U is rounded up value of $2u_c$.

In the case of R, worst case systematic error is given by

$\Delta R = R'[(V_A \Delta V_A - V\Delta V)/ V_{R''}^2 - (V_A^2 - V^2)\, \Delta V_{R'} / V_{R''}^3]$ and $u_{sy}(R) = \Delta R/\sqrt{3}$.

The standard uncertainty due to resolution in measurement is accepted as equal to 0.3 of the least count. On 20 V range the least count is 0.01 V. So the standard uncertainty is 0.003 V. The standard uncertainty in R due to resolution is given by

$u_{res}(R) = R'[(V_A \times 0.003)^2 + (V \times 0.003)^2 / V_{R''}^2 + \{(V_A^2 - V^2) \times 0.003 / V_{R''}^3\}]^{1/2}$.

$Z^2 = R^2 + X^2$. Therefore, $u(X) = [(Zu(Z))^2 + (Ru(R))^2]^{1/2}$; $u(Z) = \sqrt{[(u_{sy}^2(Z) + u_{res}^2(Z)]}$.