Problem 1: Electrical Blackbox: Capacitive Displacement Sensor

Part 1. Calibration (3.0 Points)

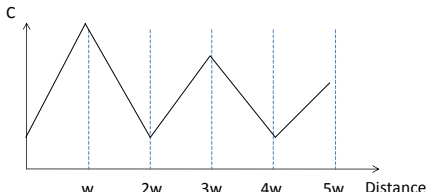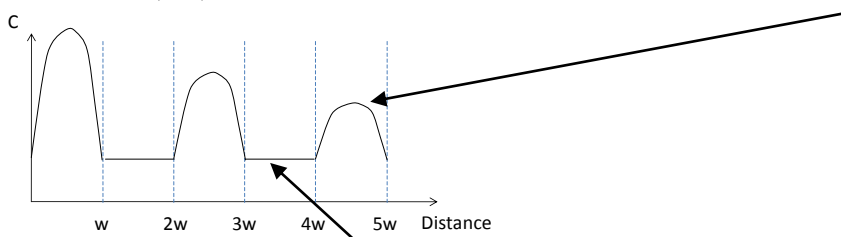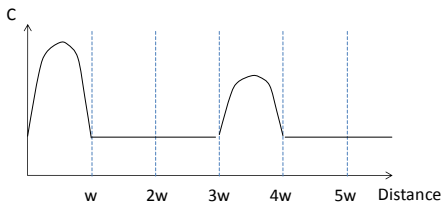| Physical concepts/Understanding (1.3 Points) (Marks awarded: either full marks or zero)	
Points	**Concepts/Details**
0.4	**P1** Adding capacitance values by parallel configuration = check from values
0.4	**P2** At least one capacitance pair add up to be more than 151 pF
0.5	**P3** Plotting C and $1/f$ to form straight line graph or Plotting fC and f to form straight line graph Other graphs not allowed
Experimental skills and Analysis (1.2 Points)	
0.3	**E1** Measurements/data table of f and C (0.2). At least 2 correct units (0.1)
0.6	**E2** Graph: -> range of values along horizontal axis at least half a page (0.1) -> range of values along vertical axis at least half a page (0.1) -> correct plotting of data (0.2) -> horizontal axis units (0.1) -> vertical axis units (0.1)
0.3	**E3** Quality of data – number of data points: Options: at least 4 data points (0.3) or 3 or less (0)
Accuracy and uncertainties (0.5 Points)	
0.5	**A1** value of α 600 – 800 pF/ms (0.3) value of C_s 5 – 35 pF (0.2) Other values (0) Deduct 0.1 point if missing or incorrect unit Deduct 0.1 if more than 4 significant figures.

Part 2. Determination of geometrical shape of a parallel plate capacitor (6.0 Points)

Points	Concepts/Details
Physical concepts/Understanding (1.4 Points) Drawing	
0.6	**P4** Plot of C versus distance (PATTERN I): -> Straight line up and down (0.3) -> Dropping/Increasing peaks on any of P4-P6 (0.2) -> Correct period of $2w$ (0.1) *(graph: C versus Distance with axis marks w, 2w, 3w, 4w, 5w)*
0.5	**P5**: Plot of C versus distance (PATTERN II) -> Options: curve with correct parabolic shape(0.2) or curve with cusp shape or like a Gaussian (0.1) *(graph: C versus Distance with axis marks w, 2w, 3w, 4w, 5w)* -> Correct period of $2w$ (0.1) -> Blank area – nearly flat/ slightly decreasing/ rounded. Successive blank areas can (but do not need to) change in level following the peaks (0.2).
0.3	**P6** Periods for PATTERN III -> Distance for non-blank area w (0.1) -> The overall period is $3w$ (0.2) *(graph: C versus Distance with axis marks w, 2w, 3w, 4w, 5w)*
Physical concepts/Understanding (1.5 Points) (Marks awarded: either full marks or zero)	
Points	Concepts/Details
0.5	**P7** Concept of parallel plate capacitor: $\dfrac{K\varepsilon_0 A}{d}$ (*A* can be replaced by formula for area)
0.5	**P8** Concept of using *the peaks* of *C* versus distance to find *b*
0.5	**P9** Concept of capacitance per sheet ΔC when varying the distance

Experimental skills and Analysis (2.6 Points)	
0.6	**E4** Table of data of x, f and C (0.4) units (0.2). Deduct 0.1 for each wrong or missing unit
0.6	**E5** Graph: -> range of values along horizontal axis at least half a page (0.1) -> range of values along vertical axis at least half a page (0.1) -> correct plotting of data (0.2) -> horizontal axis units (0.1) -> vertical axis units (0.1)
0.9	**E6** Quality of data – number of peaks: Options: 5 peaks or more (0.5), 3-4 peaks (0.3), 0-2 peaks (0) Plotting resolution: Options: about 1 mm (0.4), 2 mm (0.2), greater than 2.5 mm (0)

0.5	**E7** Find ΔC Options: use only difference between two peaks (0.1)
	    use difference between the first and last peaks (0.3)
	    average from at least 3 peaks (0.3)
	    find a slope from at least 4 peaks (0.5)
	    Use the same marking scheme if they do not use the peaks (e.g. they can use the troughs instead although this would give the wrong answer)

Accuracy and uncertainties (0.5 Points)	
0.3	**A2** value of w Options: 4.90 – 5.10 mm (0.3), other values (0) Deduct 0.1 point if missing or incorrect unit Deduct 0.1 point if more than 3 significant figures
0.2	**A2** value of b Options: 50 – 80 mm (0.2), other values (0) Deduct 0.1 point if missing or incorrect unit Deduct 0.1 point if more than 3 significant figures

Part 3. Resolution of digital calipers (1.0 Point)

Physical concepts/Understanding (0.4 Points)	
Points	**Concepts/Details**
0.3	**P10** Understand linearity of C with distance
0.1	**P11** $\Delta f = 0.01$ kHz to 0.05 kHz
Experimental skills and Analysis (0.3 Points)	
0.3	**E8** Find a slope of one section of the graph C vs. distance or f vs. distance.
Accuracy and uncertainties (0.3 Points)	

0.3	**A3** value of Δx Options: (1.5-1.8 mm/kHz)Δf (0.3)
	                            (1.0-1.4 mm/kHz)Δf or (1.9-2.2 mm/kHz)Δf (0.1)
	                            other values (0)
	 Deduct 0.1 point if wrong or missing unit
	 Deduct 0.1 point if more than 3 significant figures