Question Number	Answer	Mark
3(a)(i)	**Max TWO from** • The vernier calipers have a smaller resolution **Or** the vernier calipers have a lower uncertainty **(1)** • The vernier calipers can measure without parallax error **(1)** • Tips of vernier calipers are easier to align with the rings (as surface is curved) **(1)**	**2**
3(a)(ii)	• Repeat the measurement **and** calculate a mean value **(1)** • Measure the diameter in different orientations **(1)** If no other marks awarded, allow 1 mark for "check for zero error before measuring"	**2**
3(b)(i)	• Calculation of mean value using all three values **(1)** • Mean $a = 1.22 \times 10^{-18}$ (m^2 V) rounded to 3 s.f. **(1)** <u>Example of calculation</u> Mean value of $a = (1.23 + 1.11 + 1.32) \times 10^{-18} / 3 = 1.22 \times 10^{-18}$ m^2 V	**2**
3(b)(ii)	• Use of half their range for uncertainty [Accept use of furthest value from the mean] **(1)** • Percentage uncertainty = 9 (%) e.c.f. 3(b)(i) **(1)** <u>Example of calculation</u> Uncertainty = half range = $(1.32 - 1.11) \times 10^{-18} / 2 = 0.105 \times 10^{-18}$ m^2 V Percentage uncertainty = $(0.105 \times 10^{-18} / 1.22 \times 10^{-18}) \times 100 = 8.6$ %	**2**
3(b)(iii)	**Max TWO from** • More pairs of values were used • Adding a line of best fit acts as an averaging method **(1)** • Adding a line of best fit can identify anomalous values **(1)** • The gradient value will ignore any systematic error **(1)** **Or** the line/intercept will identify any systematic error [accept named examples of systematic error, e.g., zero error] **(1)**	**2**
3(c)(i)	• Use of $a = \frac{h^2}{2em_e}$ **(1)** • $h = 6.52 \times 10^{-34}$ (J s) **(1)** <u>Example of calculation</u> $h = \sqrt{(2 \times 1.6 \times 10^{-19} \times 9.11 \times 10^{-31} \times 1.46 \times 10^{-18})} = 6.52 \times 10^{-34}$ (J s)	**2**
3(c)(ii)	**EITHER** **(1)** • Calculation of upper limit of h **(1)** • Conclusion based on comparison to 6.63×10^{-34} J s e.c.f. 3(c)(ii) For 1 mark only – accept the calculation of 6% limit of 6.63×10^{-34} J s **OR** • Calculation of percentage difference from 6.63×10^{-34} J s e.c.f. 3(c)(i) **(1)** • Conclusion based on comparison to 6 % **(1)** <u>Examples of calculation</u> Upper limit of $h = 6.52 \times 10^{-34} \times 1.06 = 6.92 \times 10^{-34}$ J s As this is above value of 6.63×10^{-34} J s then the calculated value is accurate Percentage difference = $((6.63 - 6.52) \times 10^{-34} / 6.63 \times 10^{-34}) \times 100 = 1.7$ % As this is less than 6 % then calculated value is accurate	**2**
	Total for question 3	**14**